Synthesis and Assessment Product 4.6

Analyses and Effects of Global Change on Human Health and Welfare and Human Systems

Chapter 1: Introduction

Convening Lead Author: Janet L. Gamble, U.S. Environmental Protection Agency

Lead Authors: Kristie L. Ebi, ESS, LLC, Frances G. Sussman, Environmental Economics Consulting, Thomas J. Wilbanks, Oak Ridge National Laboratory

Contributing Authors: Katharine Hayhoe, Texas Tech University, John V. Thomas, U.S. Environmental Protection Agency, Christopher P. Weaver, AAAS Fellow

1.1 Scope and Approach of the SAP 4.6

The Global Change Research Act of 1990 (Public Law 101-606) calls for the periodic assessment of the impacts of global environmental change for the United States. In 2001, a series of sector and regional assessments were conducted by the U.S. Global Change Research Program as part of the First National Assessment. Subsequently, the U.S. Climate Change Science Program developed a *Strategic Plan* (CCSP 2003) calling for the preparation of 21 synthesis and assessment products (SAPs) to inform policy making and adaptive management across a range of climate-sensitive issues. Synthesis and Assessment Product 4.6 examines the effects of global change on human systems. This product addresses Goal 4 of five strategic goals in the CCSP *Strategic Plan* to “understand the sensitivity and adaptability of different natural and managed ecosystems and human systems to climate and related global changes”(CCSP 2003). The “global changes” assessed in this report include: those related to climate change, those related to climate variability and those derived from shifting patterns of land use within the United States and associated changes in the nation’s population patterns. While the mandate for the preparation of this report calls for evaluating the impacts of <u>global</u> change, the emphasis throughout are those impacts associated with climate variability and change. Collectively, global changes are human problems, not simply problems for the natural or the physical world. Hence, this SAP examines the vulnerability of human health and socioeconomic systems to climate variability and change across three foci of potential impacts and adaptations: human health, human settlements and human welfare.

The report’s authors included a Convening Lead Author from the Environmental Protection Agency, three Lead Authors for each of the topic chapters and a team of 28 contributing authors. The audience for this report includes public health practitioners, resource managers, urban planners, transportation planners, elected officials and other policy makers, and concerned citizens.

Chapter 2 provides a synthesis chapter specifically designed to appeal to a wide range of readers, including non-scientists, policy makers, resource managers and resource planners, interested citizens, and others who have a stake in understanding the potential consequences of climate change on human systems. Chapter 2 synthesizes findings from across Chapters 3-5, focusing on several organizing themes.

Chapters 3-5 describe the impacts of climate variability and change on human systems and outline opportunities for adaptation and associated near- and long-term research needs. SAP 4.6 addresses the questions of how and where climate variability and change may impact U.S. social systems. The challenge for this project is to derive an assessment of risks associated with health, welfare, and settlements and to develop timely adaptive strategies that address wide-ranging human vulnerabilities. Successful risk assessment classifies impacts of climate variability and change across an array of characteristics, including: the magnitude of risk (both baseline and incremental risks), the distribution of risks across populations (typical responders v. maximum-exposed individuals), and the availability, difficulty, irreversibility, and cost of adaptive alternatives. The primary goals for adaptation to climate variability and change are:

(i) To avoid maladaptive responses;
(ii) To manage significant risks proactively when possible;

(iii) To establish protocols to detect and measure risks;
(iv) To leverage technical and institutional capacity;
(v) To reduce current vulnerabilities to climate variability and change, and
(vi) To develop adaptive capacity to address new climate risks that exceed conventional adaptive measures.

Key to successful adaptation is the recognition that adaptive strategies are processes that play out across time. Needs we identify and respond to today are expected to evolve with the passage of time. Furthermore, as individuals respond to climate change they may yield substantial individual, in addition to collective, goods.

Chapter 3 assesses the potential impacts of climate variability and change on four health endpoints in the United States: water and foodborne diseases, vector and zoonotic diseases, human morbidity and mortality associated with changes in air quality, and human morbidity and mortality associated with extreme weather events and temperature extremes. For each of the health endpoints, the assessment addresses a range of topics, including:

- characterization of human health impacts from climate change in the United States;
- characterization of potential indirect effects;
- adaptation opportunities and support for effective decision making; and
- an overview of important research gaps.

The first part of the chapter focuses on the impacts of global change --- with an emphasis on those of climate variability and change --- on human morbidity and mortality. The assessment includes research published from 2001 through early 2007 in the U.S., or in Canada, Europe, and Australia, where results may provide insights for U.S. populations. The second section focuses on adaptation to the potential health impacts of climate variability and change, including public health interventions that could be revised, supplemented, or implemented to protect human health in response to the challenges and opportunities posed by climate change.

Chapter 4 focuses on the impacts and adaptations associated with climate change on human settlements in the United States. The IPCC Third Assessment Report (IPCC, 2001) concludes that settlements are among the human systems that are the most sensitive to climate change. For example, projected changes in climate extremes could have devastating consequences for human settlements that are vulnerable to droughts and wildfires, coastal and riverine floods, sea level rise and storm surge, heat waves, avalanches, land slides, and windstorms. While specific changes in these conditions cannot yet be predicted with great certainty, climate change is likely to increase the frequency and severity of some if not all of these events. Chapter 4 focuses on the interaction between settlement characteristics and climate and other global stressors, with a particular focus on urban areas and densely-developed population centers in the U.S. Because of their high population density, urban areas multiply human risk, especially where there are high percentages of the very old, the very young, the poor, the disabled and the chronically ill. In addition, because of the scale and complexity of these built environments, transportation networks, the energy and resource demands, and the interdependence of these systems and the populations they serve, urban areas are vulnerable to multiplying impacts in response to externally imposed environmental stresses. The collective vulnerability of American urban centers is expected to grow over time as a disproportionate share of urban growth is likely to concentrate population in areas like the Inter-Mountain West or the Gulf Coast. The focus of Chapter 4 is on high density and or rapidly growing settlements and the potential for changes over time in the vulnerabilities associated with their **place-based** characteristics (such as climatic regime, elevation, and proximity to coasts and rivers) and their **form-based** characteristics (such as whether development patterns are sprawling or compact).

Chapter 5 focuses on the impacts of climate variability and change on human welfare. Human welfare is an elusive concept, and there is no single, commonly-accepted definition or approach to thinking about welfare. Yet there is a shared understanding that increases in human welfare are associated with improvements in individual and group life conditions in areas such as economic power, social contacts, and opportunities for leisure and recreation along with reductions in injury, stress, and loss. The physical environment, with climate as one aspect, is among many factors that can affect human welfare via economic, physical, psychological, and social pathways that influence individual perceptions of quality of life. At a minimum, climate variability and change may result in lifestyle changes and adaptive behavior with both positive and negative welfare implications. More generally, studies of climate change in the U.S. identify an array of impacts on human health, on the productivity of human and natural systems, and on human settlements. Many of these impacts are likely to be linked to human welfare. To examine the impacts of climate variability and change on human welfare, this chapter reports on two relevant bodies of literature: approaches to welfare that rely on qualitative assessment and quantitative measures, and the economic approach which monetizes, or places money values, on quantitative impacts.

The remainder of this introductory chapter is designed to provide the reader with an overview of the current state of knowledge regarding

(1) likely changes in climate and climate variability in the United States along with

(2) a general discussion of population trends, migration patterns, and the distribution of population across settlements in the U.S.

1.2 Climate Variability and Change in the United States: Context for an Assessment of Impacts on Human Systems

In the following chapters, the authors examine the likely impacts on human society of global change, especially the impacts of climate variability and change. The impact assessments in Chapters 3-5 do not rely on specific emissions and/or climate change scenarios but, instead, refer to widely-held scientific understanding of climate change and its impacts on social systems and human health and well-being in the United States. This report does not make quantitative projections of specific impacts in specific locations based on specific projections of climate drivers of these impacts. Instead the report adopts a vulnerability perspective that blends a current understanding of climate change that has already occurred with changes that are likely to occur. The report points to vulnerabilities and then, where possible, points to the likely direction and range of potential climate-related impacts.

The brief overview that follows summarizes observed changes in the global climate reported in *The Summary for Policy Makers* as part of the Intergovernmental Panel on Climate Change Fourth Assessment Report (Alley, R. et al. 2007). This introduction is intended for readers who would benefit from a short discussion of climate change as a context for the following chapters on impacts and adaptation. The general findings of the Fourth Assessment include the following observations:

- "Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperature, widespread melting of snow and ice, and rising global average see level."
- "Eleven of the last twelve years rank among the 12 warmest years in the instrumental record of global surface temperatures."
- "Urban heat island effects are real but local."
- "Average temperature of the global ocean has increased to depths of at least 3000 m with warming that causes sea water to expand, contributing to sea level rise."
- "Mountain glaciers and snow cover have declined on average in both hemispheres."
- "The frequency of heavy precipitation events has increased over most land areas, consistent with warming and observed increases of atmospheric water vapor."
- "Widespread changes in extreme temperatures have been observed over the last 50 years, with hot days, hot nights, and heat waves becoming more frequent."
- "There is observational evidence for an increase of intense tropical cyclone activity in the North Atlantic since about 1970 (Alley, R. et al. 2007)"

In addition to the projected changes described in the IPCC *Summary for Policy Makers* (Alley, R. et al. 2007), we include a brief discussion of the historical record and trends in U.S. climate for temperature means and extremes, trends in precipitation, extremes in heat and hydrology, rising sea level, and the potential for changes in the intensity of hurricanes and other catastrophic storms. Taken together, these descriptions provide a context from which to assess the likely impacts of climate variability and change on human health, human welfare, and human settlements that form the basis for Chapters 2-4.

Rising temperatures. Climate change is already affecting the United States. According to long-term station-based observational records such as the Historical Climatology Network (Karl et al., 1990; Easterling et al., 1999; Williams et al., 2005), temperatures across the continental U.S. have been rising at a rate of 0.1oF per decade since the early 1900s. Increases in average annual temperatures over the last century now exceed 1oF (Figure 1a).

Trends in annual and seasonal precipitation. Shifting precipitation patterns have also been linked to climate change. Over the last century, annual precipitation across the continental U.S. has been increasing by an average of 0.18 inches per decade (Figure 1b). Broken down by season, winter precipitation around the coastal areas, including the West, Gulf, and Atlantic coasts, has been increasing by up to 30% while precipitation in the central part of the country (the Midwest and the Great Plains) has been decreasing by up to 20%.

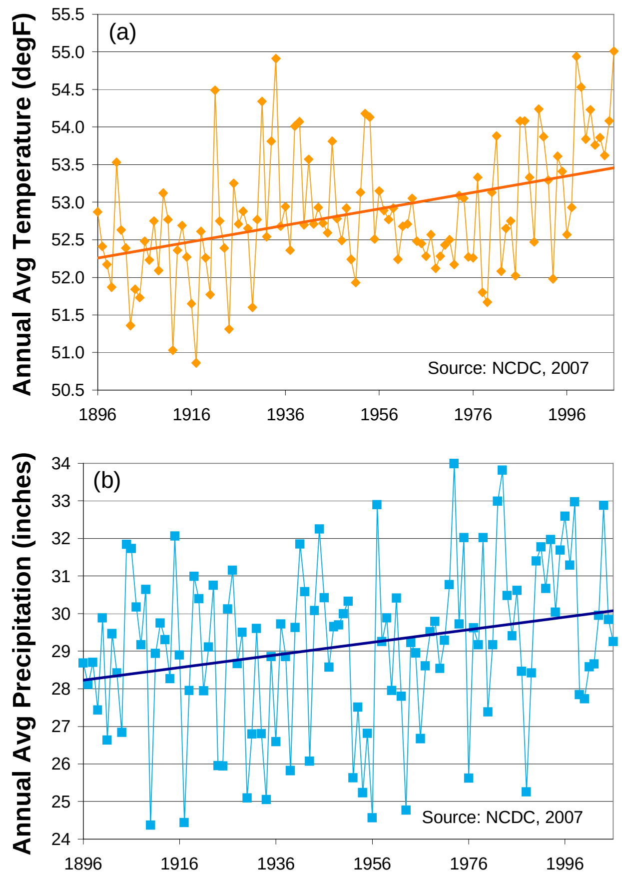


Figure 1. Observed trends in annual average (a) temperature (^{o}F) and (b) precipitation (inches) across the continental United States from 1896 to 2006 (Source: NCDC, 2007)

Large-scale spatial patterns in summer precipitation trends are more difficult to identify, as much of summer rainfall comes in the form of small-scale convective precipitation. However, it appears that there have been increases of 20-80% in summer rainfall over California and the Pacific Northwest, and decreases on the order of 20-40% across much of the south. As the Fourth Assessment Report finds, rainfall is arriving in more intense events (Alley et al., 2007).

Temperature-driven changes in extreme heat and hydrology. According to the latest IPCC findings (Alley et al., 2007), warming temperatures are already causing widespread changes in many aspects of the climate system. Prolonged heat waves are becoming more intense and lasting longer, both here in the U.S. and around the world (Frich et al., 2002).

Warmer temperatures are also melting mountain glaciers, with Glacier National Park projected to be glacier-free as early as 2030 (Hall & Fagre, 2003). More winter precipitation in northern states is falling as rain instead of snow (Huntington et al., 2004). Snow pack is also melting faster, affecting stream flow in rivers. Over the last fifty years, changes in the timing of snow melt has shifted the schedule of snow-fed stream flow in the western part of the country by 1-4 weeks earlier in the year (Stewart et al., 2005). The seasonal "center of stream flow volume" (i.e., the date at which half of the expected winter-spring stream flow has occurred) also appears to be advancing by on average 1 day per decade for streams in the Northeast (Huntington et al., 2003).

Rising sea levels and Atlantic storm intensity. Sea levels are rising at an increasing rate. The main cause for observed sea level rise over the past century is the fact that the oceans are absorbing about 80% of the additional heat being trapped in the earth-atmosphere system by greenhouse gases. This trapped heat is causing the ocean waters to expand, raising sea levels around the world. Over the first part of the century, sea level was rising at a rate of just 0.7 inches per decade (1.7 mm/yr). Over the last few decades, however, sea level has been rising nearly twice as fast, at 1.2 inches per decade (3.1 mm/yr; Alley et al., 2007). Some of this recent increase may be due to the observed acceleration in the rate of Greenland ice melting over the past decade (Rignot, 2006).

Even by themselves, rising sea levels will exacerbate the impacts of coastal storms. However, the intensity of Atlantic hurricanes and tropical cyclones has also been increasing over the last few decades. According to the IPCC, increased intensity is "as likely as not" due at least in part to warming sea surface temperatures (Emanuel, 2005; Webster et al., 2005; Alley et al., 2007). The combination of higher sea levels with more intense storms further raises the risk of serious climate change impacts on coastal zones.

Extremes. Although no single extreme event can be directly attributed to climate change, many events typical of what it is likely we can expect in the future (Alley et al., 2007) have occurred in recent decades. These include the very warm summers and prolonged heat waves of 1988, 1995, 1998, 1999 and 2006 (Karl and Knight, 1997; Ross & Lott, 1999; Stott, 2004; Meehl & Tebaldi, 2004). These heat waves affected air quality and led to significant increases in heat-related morbidity and mortality, particularly in urban areas (Semenza et al., 1996; Whitman et al., 1997). They also led to billions of dollars in agricultural losses (Ross & Lott, 1999).

Extreme events typical of what may be expected in the future also include the numerous periods of heavy downpours that have led to documented increases in flood-related losses across the continental U.S. (Chagnon, 2003). In general, more rain is falling during heavy rainfall events, and these have increased in frequency by as much as 100% across much of the Midwest and Northeast over the last century (Kunkel et al., 1999).

Finally, the intense hurricanes that battered the Gulf Coast in 2005 cannot be directly attributed to climate change alone. However, the likelihood of stronger storms appears to have increased over the past few decades (Emanuel, 2005). Furthermore, these events are certainly indicative of what may be expected in the future under higher sea levels combined with equally or even more intense storms (Knutson & Tuleya, 2004). Together, the heat waves, heavy downpours and flooding, and coastal storms experienced in recent years give us a foretaste of what we might expect to see in the future due to climate change.

1.3 Population Trends, Migration Patterns, and Development of the Nation's Landscape: A Context for Assessing Climate-related Impacts

Just as the preceding discussion of climate variability and change provides a framework for understanding impacts on human health, settlements and welfare, an overview of population trends and settlement patterns provides the basis for assessing broader interactions of global change, especially climate change, within the larger social context . Underlying many of the studies discussed in this report are assumptions about U.S. population projections across the next 20, 50 or 100 years. At the intersection of the impacts of climate variability and change, are impacts associated with demographic factors and region-specific effects. The results of impacts or risks assessments are shaped by questions such as:

- *Which coastal counties will grow most rapidly?*
- *How many more people do we expect to move into arid states in the Mountain West?*
- *What level of international immigration can we expect and which communities will be the primary gateway destinations?*
- *Which currently rural counties will become urban?*
- *What share of retirees will migrate and where will they move?*

Detailed assessments of climate-related risk make assumptions about the size and distribution of the U.S. population. These baseline projections can be done at three basic levels: 1) across the fifty states, 2) within states and regions, and 3) within cities and neighborhoods.

Given the technical and computational challenges of downscaling model-based climate change projections, quantitative impact studies tend not to address impacts at the city and neighborhood scale. This is a critical gap in the existing literature since many impacts such as: heat related deaths, exposure to vector borne disease, storm damage to uninsured property and heat induced changes in air quality do vary at this scale (Borrell et al., 2006, Patz et al., 2005, Naughton et al., 2002, McGeehin and Mirabelli 2001). This variation may be important, because vulnerable populations, like seniors, low income families, and others with more limited access to health care and property insurance who are already disproportionately impacted by climate variability and change, are often concentrated in particular urban neighborhoods. Better understanding of climate change at the community scale would provide a basis for adaptation research that addresses environmental justice / equity concerns (Rosenthal and Brandt-Rauf 2006, Bernard and McGeehin 2004).

While precise population forecasts are not feasible over long time frames, many rigorous scenarios have been developed at the national, state and regional scale. The scenarios typically provide a benchmark future for the assessments of climate change impacts. At the state level, the Census Bureau regularly produces 25-year predictions. Most states also produce county level forecasts consistent with the Census projections. While some impact studies have relied on these official population estimates, others have employed economic or land allocation models to develop independent baseline scenarios.

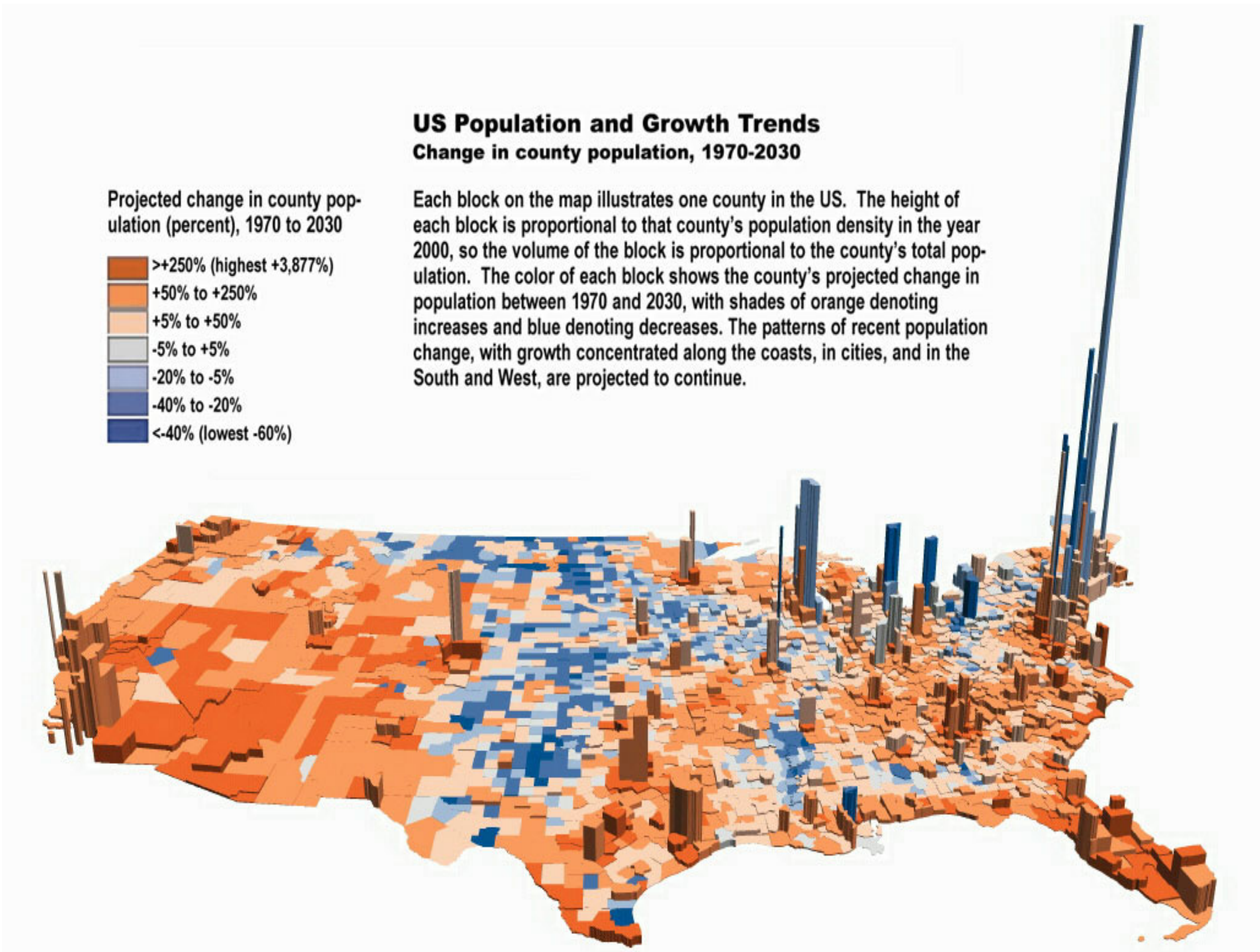


Figure 1.1: U.S. Population and Growth Trends with evidence of more pronounced growth projected along the coasts, in urban centers, and in cities in the South and West (NAST, 2001).

Although numbers produced by population forecasts are important, the striking relationship between the most likely impacts of climate change and the most likely future settlement patterns is the critical insight. *In particular, nearly all trends and forecasts point to more Americans living in areas most vulnerable to the effects of climate change.* For example, many rapidly growing places in the Mountain West are also most likely to experience decreased snow pack during winter and earlier spring melting of what snow pack there is, leading to lower stream flows, particularly during the high-demand period of summer. The most rapidly growing coastal counties also tend to be in areas most prone to hurricane activity and to storm surge. With continued growth in these vulnerable regions, research is needed to consider alternative growth futures and to minimize the vulnerability of new development, to insure that communities adopt measures to manage significant changes in sea level, temperature, rainfall and extreme weather events.

National Population Trends

- Since 1980 the U.S. population has grown by more than 40 million
- However, the growth has been unevenly distributed
    - More than 500 counties actually lost population
        - Over 2 million fewer people live in these areas
    - While just 40 counties accounted for more than half the growth (either from migration or natural increase)
        - Ranging from 2.5 million in Los Angeles County to just over 200,000 in Polk County, Florida.
- Over the next 25 years the U.S. is expected grow by more than 60 million
    - 7 states are expected to account for more than two-thirds of this growth (Florida, Texas, California, Arizona, North Carolina, Georgia, and Washington)
    - Large urban and coastal counties will continue to account for the majority of growth, although many rural and urban fringe counties will grow rapidly in percentage terms.

Source: US Census Bureau, 2005

Movement toward coastal areas has been one of the most pronounced trends over the past few decades and the trend is expected to continue. The overlay of this migration pattern with climate change forecasts has several implications. Perhaps the most obvious is the increased exposure of people and property to the effects of sea level rise and hurricanes. With rapidly growing communities near coastlines, property damages would be expected to increase even without any changes in storm frequency or intensity. If sea level rise intensifies storm surges and extreme weather events become more frequent, the negative impacts and adaptation challenges will be compounded by intensely-developed coastal zones.

The continued growth of arid states in the West is another critical crossroads for human settlements and climate change. Eleven states have significant reservoir capacity that would most likely be impacted by a significant change in precipitation and snowfall (see figure). These states are also expected to account for one-third of all U.S. population growth over the next 25 years (US Census Bureau, 2005). This dual challenge of decreased water supply in the face of rising demand is yet another example of a critical pressure point between population trends and climate change projections. For example, a study commissioned by the California Energy Commission estimated that the Sierra Mountain snow pack could be reduced by 12 to 47% by 2050 (Cayan et al 2006). At the same time, State projections anticipate an additional 20 million Californians by that date (California Department of Finance 2004). States in the Northeast and Midwest will most likely continue to see substantial out-migration to the South and West.

However, immigration from abroad and natural population increase are expected to generate some amount of population growth in nearly all states.

Within regions, two competing trends have emerged. Over the past century, advances in transportation technology – electric streetcars, freight trucks, personal automobiles, and the interstate highway system -have fueled the decentralization of urban regions (Hanson and Giuliano 2004, Garreau 1991, Lang 2003). While the Internet and telecommunications technology have contributed to this trend, they have also made central cities more important engines of economic growth (Graham and Marvin 1996, Castells 1996, Sassen 2002). Not surprisingly, most of these global cities – New York, Miami, Los Angeles, San Francisco and Seattle - are also in coastal regions. Historically, gateway cities have often been port cities, with a history of development based on easy access for immigrant populations and for international trade. During the 1990's, most large central cities experienced population growth, reversing long-standing trends.

Overall, the rate of land development at a national level has been fairly consistent over the past 20 years. However, across the 50 states, the acres of land developed for every additional person varies from less than a quarter acre per person in California and Hawaii to more than an acre per additional person in 16 states. In other words, some regions have grown rapidly with relatively modest increases in developed land, while other regions have increased the amount of developed land in spite of declining populations (NRCS 2007). The potential for regional land use policy to affect climate change impacts and adaptation opportunities seems clear. Metropolitan areas concentrate climate impacts on densely-populated urban areas that in turn multiply the climate effects in these heavily-developed business centers.

Another trend of significance for climate change is the suburbanization of poverty. A recent study noted that by 2005 the number of low income households living in suburban communities had for the first time surpassed the number living in central cities (Berube and Kneebone 2006). Although the poverty rate in cities was still double the suburban rate, there were 1 million more people overall living in poverty in America's suburbs.

Therefore, many of these people who will be more vulnerable to the effects of climate change live in older inner-ring suburbs developed in the 1950's and 60's. The climate adaptation challenge for these places is captured succinctly by a recent policy study focusing on the broader set of public policy issues in such places:

> *"Neither fully urban nor completely suburban, America's older, inner-ring, "first" suburbs have a unique set of challenges—such as concentrations of elderly and immigrant populations as well as outmoded housing and commercial buildings—very different from those of the center city and fast growing newer places. Yet first suburbs exist in a policy blind spot with little in the way of state or federal tools to help them adapt to their new realities." (Puentes and Warren 2006)*

It is often said that Americans are a nation of movers and data collected for both the 1990 and 2000 Census support this notion. While roughly half of the U.S. population had lived in the same house for the previous five years, nearly 10 percent had recently moved from out of state

(Census 1990 STF 3 Table P043 and Census 2000 STF 3 Table P24). In other words, during the five year period preceding each Census, over 20 million Americans had moved across state lines and half of those moved to an entirely different region.

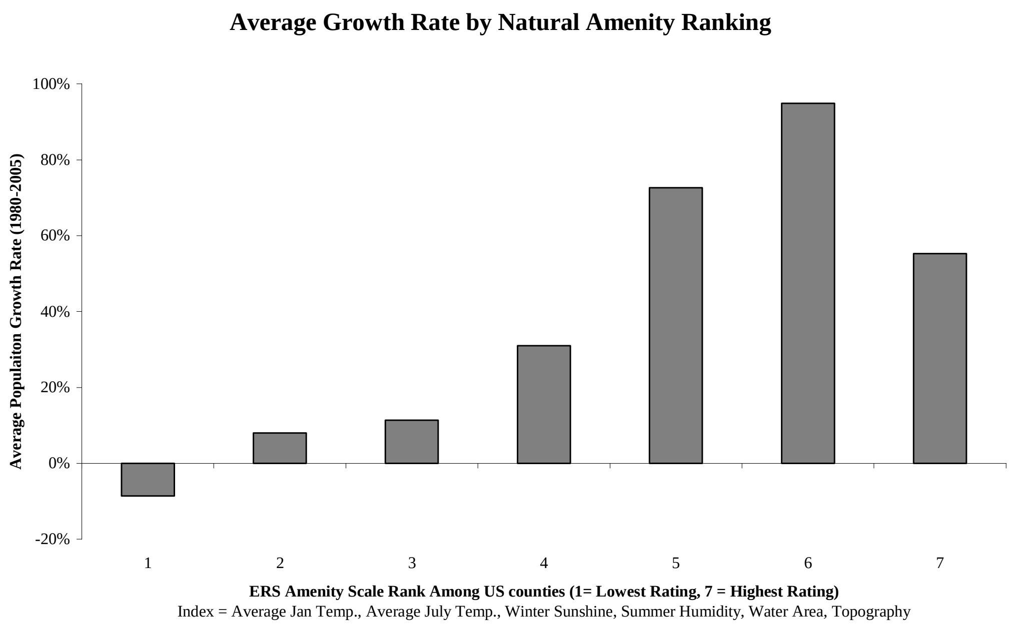
Although many forces shape domestic migration, climate is a key element of perceived quality of life. In turn, quality of life can be an important factor driving the relocation decisions of households and businesses. The popularity of the Places Rated Almanac and other publications ranking cities' livability illustrates the concept's importance. Additionally, many of the indicators in these reports are based directly on climatic conditions (average winter and summer temperature, precipitation, days of sunshine, humidity, etc.).

A range of studies have attempted to quantify how natural amenities, including a favorable climate, affect migration. While the methods have varied [1] the basic conclusions are similar. In general:

- People move for a variety of reasons other than climate: proximity to family and friends, employment opportunities, lower cost of living
- Therefore, areas with natural amenities that are close to urban centers have attracted the largest numbers of in-migrants (Serow 2001)
- Climate's impact on migration varies by income with lower income groups also moving to colder areas in which their wages are likely to compare more favorably to the cost of living (Rebhun and Raveh 2006)
- For retirees, weather is a far more important rationale cited for moving out of an area than moving to an area (AARP 2006)
- Population growth in rural counties is strongly related to a more favorable climate and other key natural amenities (McGranahan 1999)

Of particular interest are the trends among rural counties. One study identified 277 rural counties as retiree destinations, with 90 emerging as new retiree destinations in the 1990's (McGranahan 2003).[2] An overwhelming share had natural amenities that would place them among the most desirable places to live.(see figure below)[3] Studies of rapidly growing "amenity counties" suggest that jobs are increasingly following the migration of working age adults to such places (Carruthers and Vias 2005, Cromartie 1998). The obvious question for climate research is: *If some regions become less frigid in the winter and others more hot and humid in the summer, will these migration patterns change substantially?*

[1] Study methodologies include: aggregate studies of population changes alongside regional characteristics, explanatory models developed from individual migration data and individual surveys.
[2] Defined by the authors as a greater than 15% increase in the over 60 population in the previous decade.
[3] Researchers at the USDA Economic Research Service ranked counties according to a natural amenity index (average winter and summer temperature, winter sunshine, summer humidity, water area and topography)



(Source: County Amenity Index - McGranahan 1999; Population Data - US Census 2006)

Figure 1.2. Average population growth rate by Natural Amenity Index. (1980-2005). High amenity indices (based on county-level data) correlate with high population growth.

1.4 Reporting Uncertainty in SAP 4.6

We have adopted a framework for treating uncertainty in this report that is informed by ongoing discussion within the Climate Change Science Program. General guidance issued by the CCSP on handling uncertainty in the various Synthesis and Assessment Products (SAPs), draws on best practices documented in previous large assessment exercises, such as the Intergovernmental Panel on Climate Change (IPCC), as well as on new CCSP efforts. The specific application of this guidance in each SAP is a function of the subject matter and scope of the particular report.

In this report, as in the other SAPs, handling uncertainty involves characterization (of the uncertainty surrounding a finding, judgment, or prediction) and communication (of this uncertainty) in clear, precise, objective language. This characterization and communication in this report reflects the following guiding principles:

- It is important to recognize the basic differences between descriptions of uncertainty in terms of *likelihood* or in terms of *level of confidence* of the science. Likelihood is relevant when assessing the chance of defined future occurrence or outcome, often expressed in a probabilistic way. Level of confidence refers to the degree of belief in the scientific community that available understanding, models, and analyses are accurate, expressed by the degree of consensus in the available evidence and its interpretation. Both are important when dealing with climate change impacts assessments and both must be communicated.

Specifically:

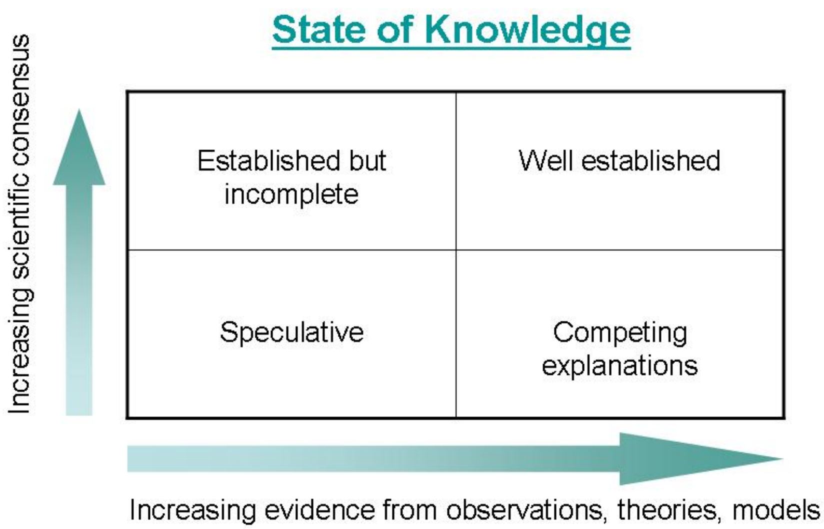
- When expressing likelihood, there are many words used to describe different degrees of uncertainty: e.g., “probable,” “possible,” “likely,” “unlikely,” etc. Such qualitative language is inadequate because the same words can mean very different things to different people, and the same words can mean very different things to the same person in different contexts. Therefore, in this report, numerical probabilities are assigned to such qualifiers (Table 1), which are then used consistently throughout the report.

Table 1. Defining the likelihood of an outcome where it can be estimated probabilistically.

Likelihood Terminology	Likelihood of the occurrence / outcome
Virtually certain	> 99% probability
Extremely likely	> 95% probability
Very likely	> 90% probability
Likely	> 66% probability
More likely than not	> 50% probability
About as likely as not	33 - 66% probability
Unlikely	< 33% probability
Very unlikely	< 10% probability
Extremely unlikely	< 5% probability
Exceptionally unlikely	< 1% probability

- When dealing with the level of confidence in our scientific judgments about climate change and its impacts, it is important to consider two attributes: the amount of evidence available to support the judgment being made and the degree of consensus within the scientific community about that judgment. The state of knowledge underlying any judgment can in principle be sorted into specific categories (e.g., see Figure 1).

Figure 1.3 State of Knowledge



Throughout this report, an evaluation of uncertainty will be presented to accompany any judgment, finding, or conclusion made in the text. If such a judgment, finding, or conclusion regards the subjective probability of a future event, for example a future projection of a specific climate change impact, the appropriate expression of likelihood (taken from Table 1) will be used. If instead the finding is an assessment of the degree of knowledge and understanding currently present in the scientific community about a topic, as expressed in the literature, the report will explicitly address questions like, “Is there a lot of literature out there dealing with this issue, or only a little?” and, “For the literature that does exist, is there broad agreement or wide disagreement?”

The application of this approach to likelihood and level of confidence estimates varies in each of the three core chapters (Chapters 3-5) according to the current richness of the respective knowledge bases. A relatively more extensive and specific application is possible for health impacts, only a more general approach is warranted for conclusions about human settlements and uncertainty statements about human welfare conclusions are necessarily the least explicit.

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