# OUR CHANGING NATION

*Over the 21st century, assuming no major wars or other catastrophes, growth is likely to continue. However, the specifics of future US growth depend upon many uncertain factors such as technological change, world trade, market conditions, and immigration.*

Climate variability and change do not occur in isolation,but in an evolving, dynamic social and economic context. This context is very likely to affect the character and magnitude of climate impacts. Socioeconomic conditions are important drivers of climate change,and also influence the way society responds to change. The prosperity and structure of the economy, the technologies available and in use,and the settlement patterns and demographic structure of the population,are all very likely to contribute to how and how much climate change will matter to Americans,and what they can and might wish to do about it.

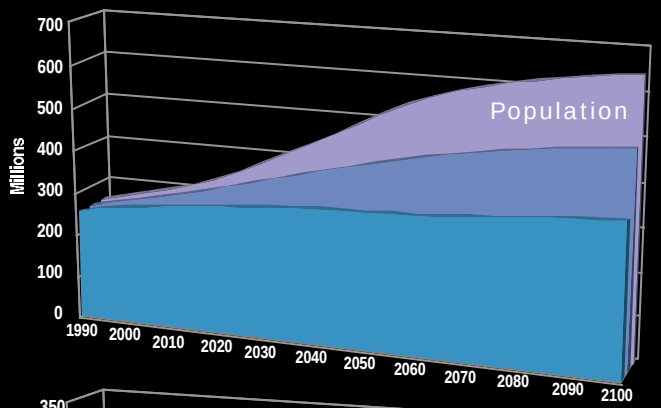
Thinking explicitly about socioeconomic futures is speculative,but doing a coherent assessment of future climate impacts requires that potential future socioeconomic conditions be considered. Failing to explicitly consider these conditions risks making the assumption that the future will be largely like the present – an assumption that is virtually certain to be wrong. To see how wrong,one need only compare America's society and economy today to that of 100,50,or even 25 years ago.

To guide our thinking about socioeconomic futures,this Assessment developed three illustrative socioeconomic scenarios,which project high,medium,and low growth trends for the US population and economy through the 21st century. These scenarios necessarily involve uncertainties that grow large by the end of the century, as the figures show. Nevertheless,they represent a plausible range of socioeconomic conditions that could affect climate impacts and response capabilities. Using multiple scenarios avoids the errors of attempting specific predictions,or assuming no change at all. Region and sector

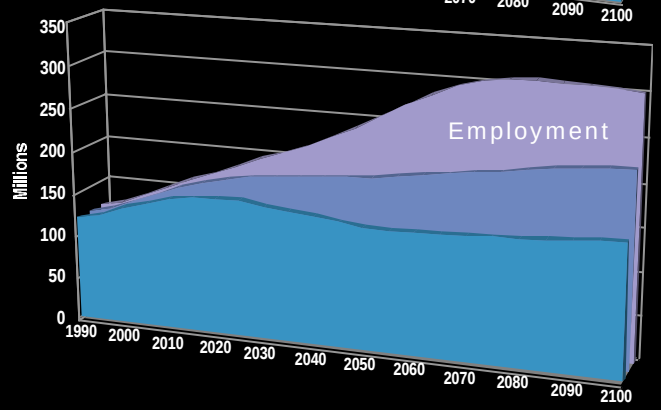
**21st Century Growth in America**

Low, Medium, and High Scenarios

**The Assessment considered high, medium, and low scenarios of future US population and economic growth. Future trends in population, economic growth, and technological change will all shape our contribution to climate change, our vulnerability to it, and our ability to adapt.**




**Through the 21st century, US population projections range from a 20% increase to a doubling, principally due to alternative assumptions of immigration trends.**




**Future employment projections track population, and also include varying rates of employment by older workers as the US population ages.**

teams were asked to use these scenarios when their analyses required demographic or economic inputs.

## Growing Prosperity

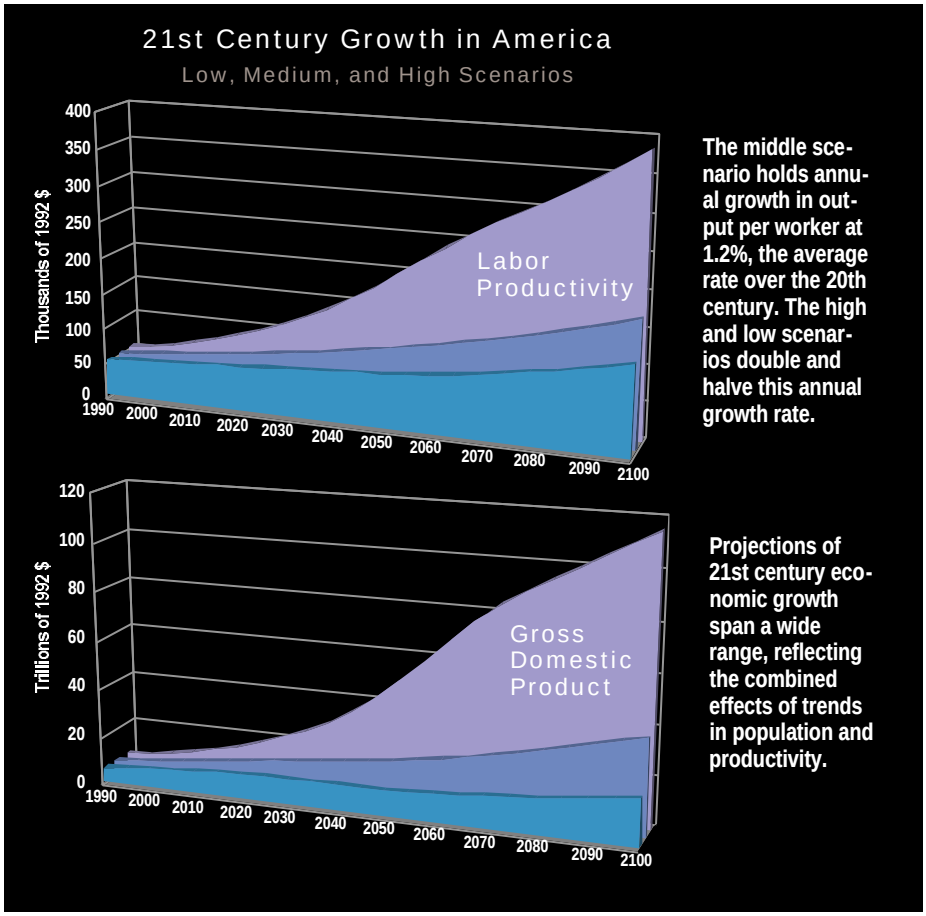
The US economy and population are growing. Barring major wars or other catastrophes, growth is likely to continue through the 21st century. If economic growth is higher, society is likely to be more able to take advantage of the opportunities a changing climate presents,and more able to cope with its negative impacts. Wealthier, industrialized societies derive less of their incomes from strongly climate-related activities than more traditional societies. With more technology and infrastructure, wealthy societies also have more resources to support adaptation,and can more easily endure climate-related losses. Within societies,some will very likely face greater burdens or greater opportunities than others. It is also possible that rapid economic growth can increase vulnerability, by increasing pollution (including greenhouse gas emissions),congestion, demand for land and resources,and stresses on natural ecosystems,and possibly their vulnerability to climate change.

## Changing Technology

Much of the recent US economic growth has been fueled by new technology. Although technological change can carry significant social and environmental costs,in aggregate it greatly increased Americans'material well being over the 20th century. For example,in the past decade,new information and communication technologies have transformed many activities,bringing increased productivity and new products and services.

Technology affects society's relationship to climate in many ways. It is very likely that technological change will strongly influence the success of any future efforts to control greenhouse gas emissions,and reduce vulnerability to climate change. For example,it is possible that information technology, combined with new cropping methods and advanced crop varieties,will increase farmers' ability to adapt to climate change or variability. Similarly, advances in medicine,public health,and information technology will likely strengthen our abilities in the early detection,prevention,and treatment of disease.

Technology can also increase society's vulnerability to unanticipated extremes of climate. This can happen because modern society is highly interdependent, relying in critical ways on electric power, transportation,and communications systems,all of which can be disrupted by extreme weather events if systems have not been adequately designed to deal with contingencies.




**The middle scenario holds annual growth in output per worker at 1.2%, the average rate over the 20th century. The high and low scenarios double and halve this annual growth rate.**

**Projections of 21st century economic growth span a wide range, reflecting the combined effects of trends in population and productivity.**

# OUR CHANGING NATION

## A Growing, Aging, and Mobile Populace

*Some 53% of the population now live in the 17% of the land area that comprises the coastal zone, and the largest population growth for several decades is projected for coastal areas.*

The US population is projected to continue growing through the 21st century, but at a declining rate. The scenarios used in this Assessment project a US population in 2100 that ranges from 353 to 640 million (representing average annual growth rates of 0.31% to 0.86% over the 21st century),with 494 million in the middle scenario. Most of this uncertainty arises from alternative immigration assumptions.

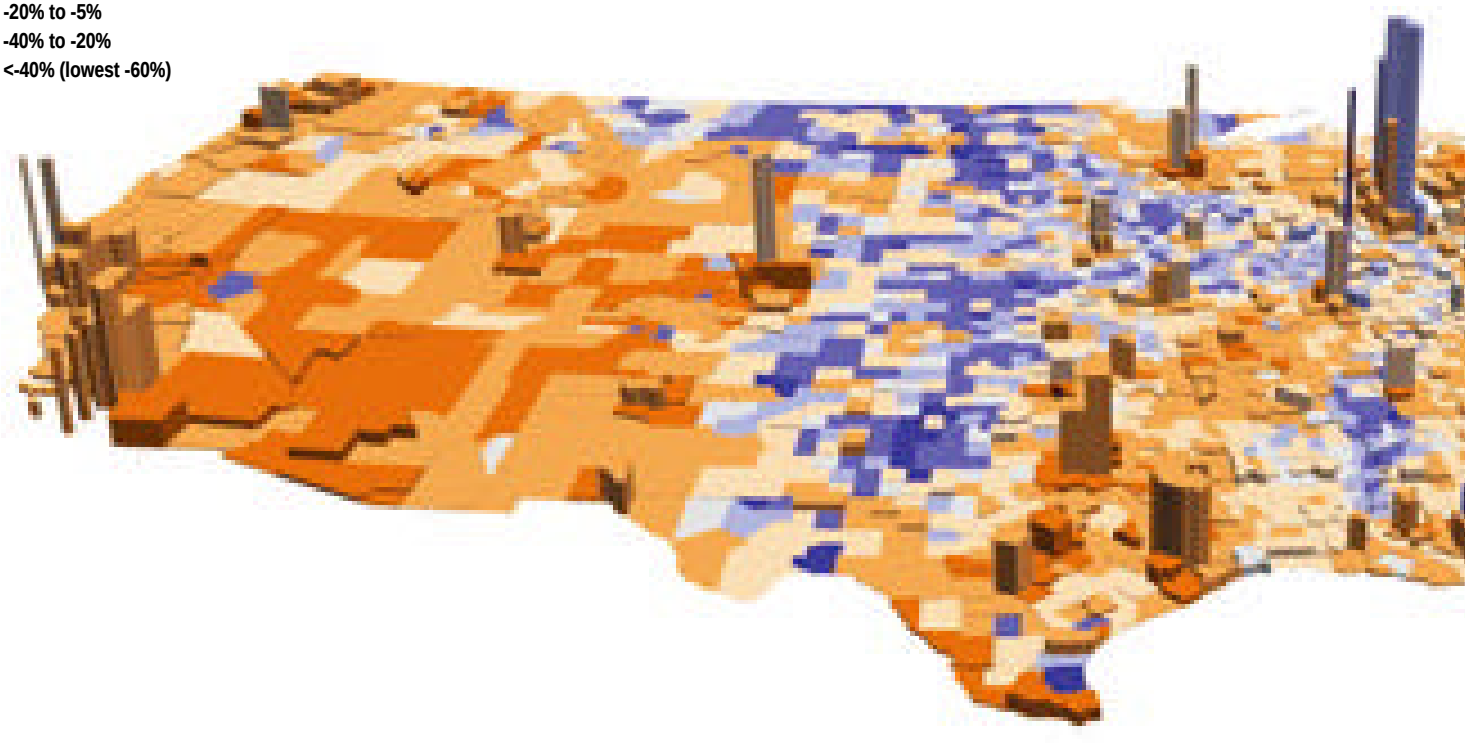
The US population is aging. Over the 20th century, the fraction of Americans over age 65 increased from 1 in 25 to 1 in 8. Older people are physiologically more vulnerable to heat stress. Without adaptive measures,a warmer climate would likely bring an increase in heat-related illness and death,which society's aging would compound. There is also some chance that warming would reduce cold-related mortality, a trend that would also interact with the aging of the population,although the data suggest a weaker effect than for heat. Many older Americans prefer warmer climates,as the migration from northern regions to the Sunbelt demonstrates. Widespread use of one technology, air conditioning, powerfully advanced the growth of these southern regions. At the same time, rapid growth in arid regions has sharply increased these regions'vulnerability to water shortages.

### US Population and Growth Trends
Change in county population, 1970-2030

**Projected change in county population (percent), 1970 to 2030**

- >+250% (highest +3,877%)
- +50% to +250%
- +5% to +50%
- -5% to +5%
- -20% to -5%
- -40% to -20%
- <-40% (lowest -60%)

**Each block on the map illustrates one county in the US. The height of each block is proportional to that county's population density in the year 2000, so the volume of the block is proportional to the county's total population. The color of each block shows the county's projected change in population between 1970 and 2030, with shades of orange denoting increases and blue denoting decreases. The patterns of recent population change, with growth concentrated along the coasts, in cities, and in the**



America is becoming more urban. The fraction of Americans living in cities increased from 40% in 1900 to more than 75% today and this increase is projected to continue. Urbanization affects vulnerability to climate and the capacity to adapt in complex ways. City dwellers are less dependent on climate-sensitive activities for their livelihoods,and have more resources and social support

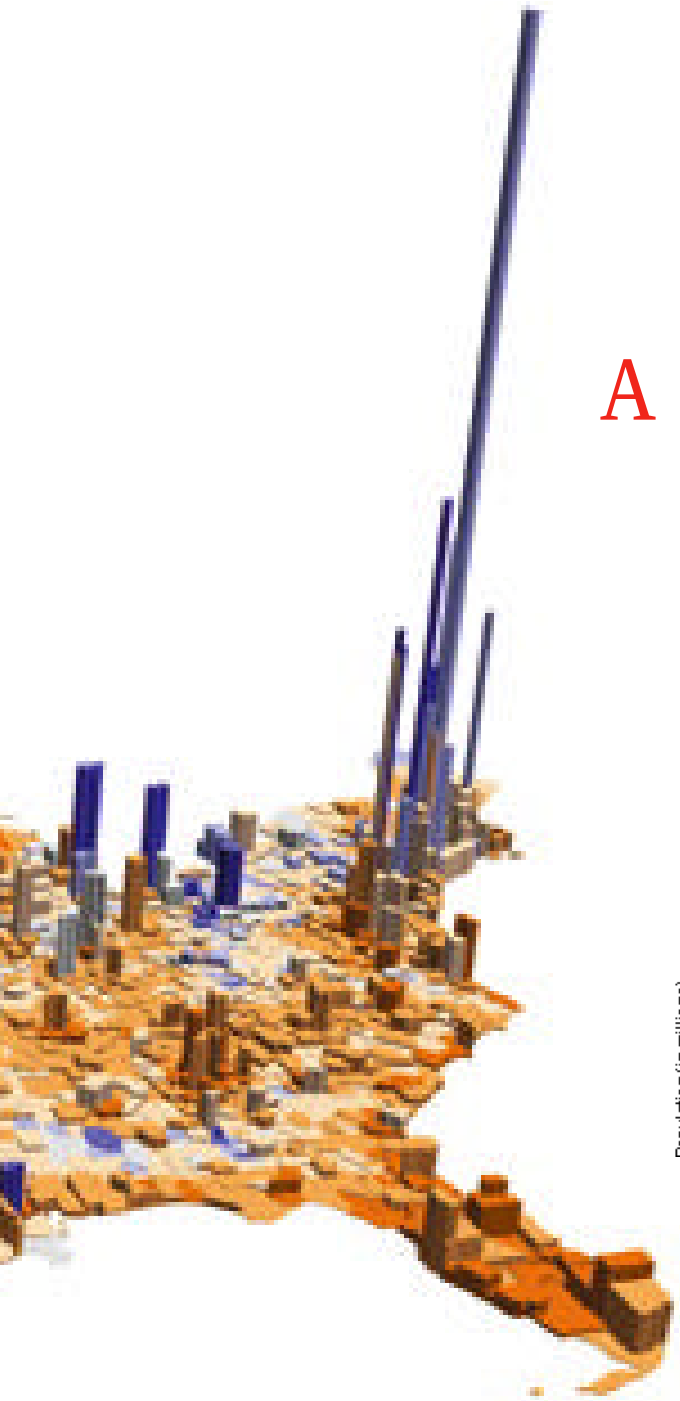
population now live in the 17% of the land area that comprises the coastal zone,and the largest population growth for several decades is projected for coastal areas. Over the next 25 years,population growth of some 18 million is projected in the coastal states of Florida,California, Texas,and Washington. This trend is exacerbating wetland loss and coastal pollution. In addition,locating more

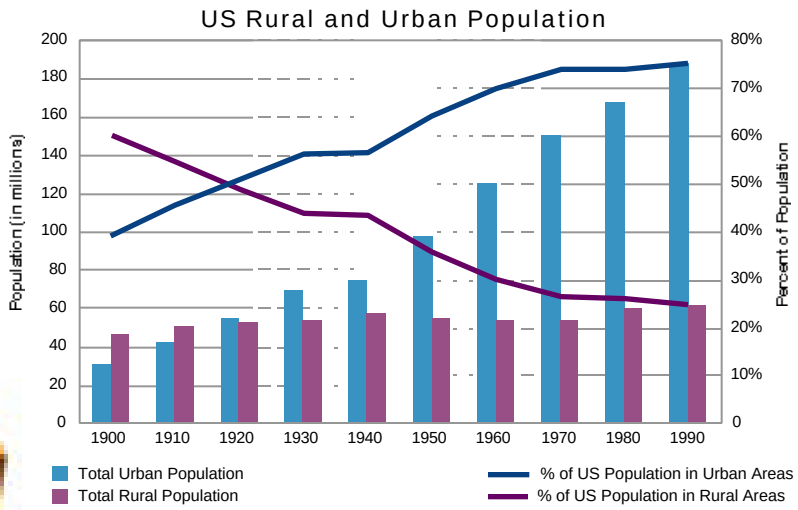
and property in low-lying areas increases vulnerability s,storm surges,erosion,and l rise – as several decades of trends,and extreme recent Florida,Georgia,and the s,all confirm.

## ng about the Future: g with Complexity

A st of other factors are also ely to affect the ease with ociety can adapt to,or take ge of, climate variability and For particular regions or sec- factors likely to shape cli- lnerability include local zon- inances,housing styles,build- es,popular forms of recre- e age and degree of special- f capital in particular indus- rld market conditions,and ibution of income. To further ate matters,many of these factors are likely to be influenced by climate variability and change,and to influence each other. Trying to project all such relevant factors,or to model their interactions, would be impossible.

Rather, this first Assessment took a highly simplified approach to projecting socioeconomic factors. When teams needed more detailed socioeconomic projections than the scenarios of population and economic growth provided,they were asked to follow a standard procedure to generate and document the projections they needed. They were asked to select one or two additional factors – such as development patterns,land use,technology, or market conditions – that they judged likely to have the most direct effect on the issue they were examining,and to vary these factors through an uncertainty range they judged plausible. This approach has clear limitations.In fact,teams found the complexity of even this simplified approach challenging,and made limited use of it beyond the basic scenarios. It has,however, allowed some preliminary investigations of the socioeconomic basis of impacts and vulnerability, which can be refined and extended as assessment methods and experience advance.






**Essentially all 20th century US population growth has been in cities, increasing the urban population fraction from 40% in 1900 to more than 75% in 1990. This move to the cities is projected to continue.**

# OUR CHANGING NATION

## Impacts, Adaptation, and Vulnerability

*While societies have shown substantial adaptability to climate variability, the challenge of adapting to a climate that is not stable, but evolving at an uncertain rate, has never been tested in an industrialized society.*

Climate impacts,vulnerability, and adaptation are distinct but related concepts. Given an assumed state of America's society and economy, the impacts of a specified climate scenario are the differences it yields relative to a continuation of the present climate. These impacts may be beneficial or harmful,with most climate scenarios bringing mixed effects:benefits to some people,places,and sectors,and harms to others. A system is more or less sensitive to climate depending on whether a specified change in climate brings large or small impacts.

People need not merely suffer the climate conditions they face,however, but can change their practices,institutions,or technology to take maximum advantage of the opportunities the climate presents and limit the harms they suffer from its variations. Through such adaptations,people and societies adjust to the average climate conditions and the variability of conditions they have experienced in the recent past. When habits,livelihoods,capital stock,and management practices are finely tuned to current climate conditions,the direct effect of many types of change in these conditions,particularly if the change occurs rapidly, is more likely to be harmful and disruptive than beneficial.

But just as societies adapt to the present climate,they can also adapt to changes in it. Adaptation can be intentional or not,and can be undertaken either in anticipation of projected changes or in reaction to observed changes. Society's capacity to adapt to future climate change is a crucial uncertainty in determining what the actual consequences of climate change will be. Societies and economies are vulnerable to climate change if they face substantial unfavorable impacts,and have limited ability to adapt. Socioeconomic conditions such as wealth,economic structure,settlement patterns,and technology play strong roles in determining vulnerability to specified climate conditions,as the history of US hurricane losses shows.

Human societies and economies have demonstrated great adaptability to wide-ranging environmental and climatic conditions found throughout the world,and to historical variability. Wealthy industrial societies like the US function quite similarly in such divergent climates as those of Fairbanks,Alaska and Orlando,Florida. While individual adaptability also contributes,it is principally social and economic adaptations in infrastructure,capital, technology, and institutions that make life in Orlando and Fairbanks so similar that individual Americans can move between them easily.

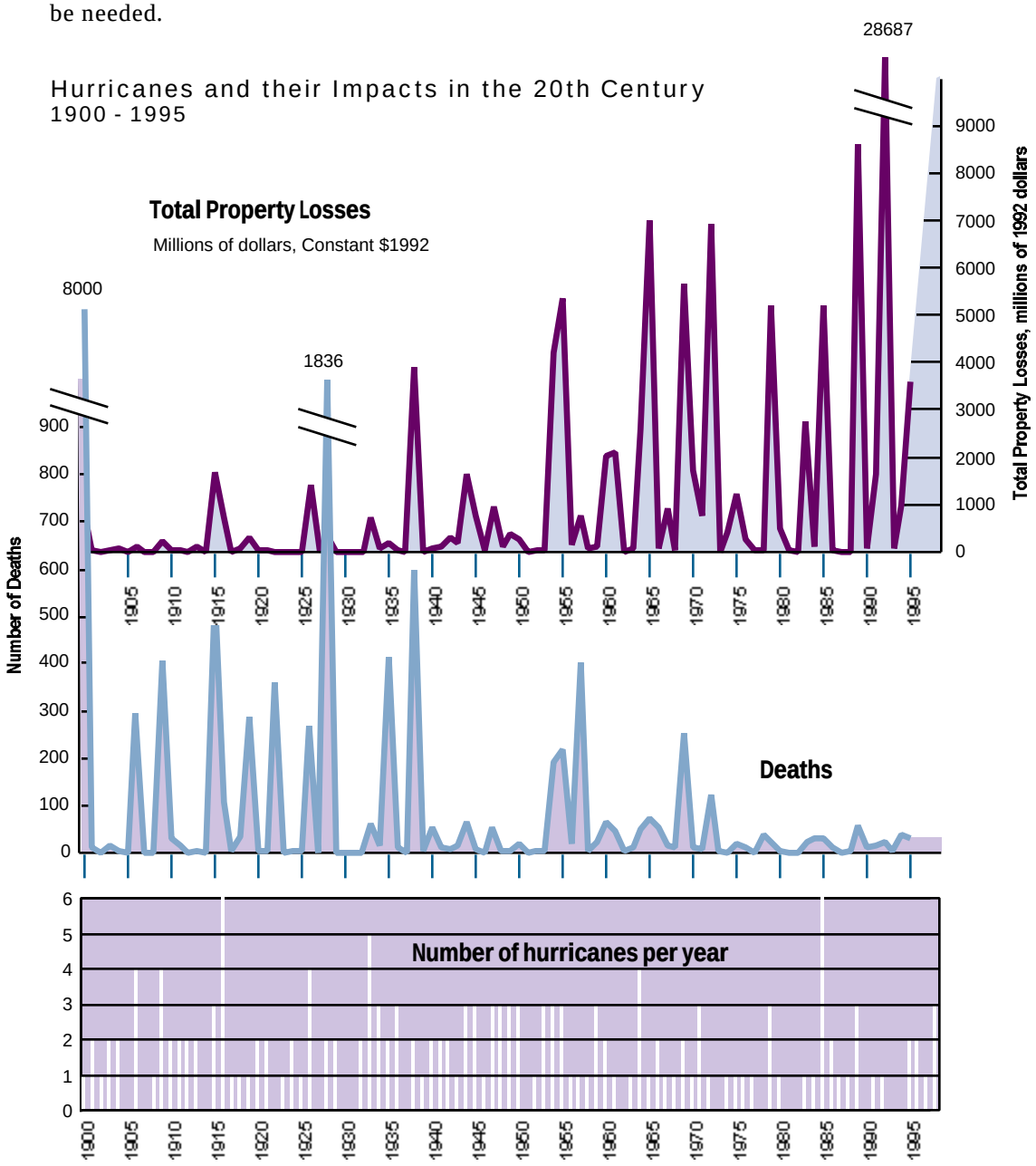
But adaptability has limits, for societies as for individuals,and individuals' ability to move through large climate differences tells us little about these limits. Moving between Orlando and Fairbanks may be easy for an individual,but rapidly imposing the climate of either place on the other would be very disruptive. The countless ways that particular local societies have adapted to current conditions and their history of variability can be changed,but not without cost,not all with equal ease,and not overnight. The speed of climate change,and its relationship to the speed at which skills,habits, resource-management practices,policies,and capital stock can change,is consequently a crucial contributor to vulnerability. Moreover, however wisely we may try to adjust long-lived decisions to anticipate coming climate changes, we will inevitability remain limited by our imperfect projections of the coming changes.Effective adaptation may depend as much on our abili-

ty to devise responses that are robust to various possible changes,and adjustable as we learn more,as on the quality of our projections at any particular moment. While societies have shown substantial adaptability to climate variability, the challenge of adapting to a climate that is not stable,but evolving at an uncertain rate,has never been tested in an industrialized society.

Consequently, while adaptation measures can help Americans reduce harmful climate impacts and take advantage of associated opportunities,one cannot simply assume that adaptation will make the aggregate impacts of climate change negligible or beneficial. Nor can one assume that all available adaptation measures will necessarily be taken; even for such well-known hazards as fire, flood,and storms,people often fail to take inexpensive and easy risk-reduction measures in their choices of building sites,standards,and materials,sometimes with grave consequences. In this first Assessment,potential climate adaptation options were identified,but their feasibility, costs,effectiveness,or the likely extent of their actual implementation were not assessed. Careful assessment of these will be needed.

*One cannot simply assume that adaptation will make the aggregate impacts of climate change negligible or beneficial.*

*In this first Assessment, potential climate adaptation options were identified, but their feasibility, costs, effectiveness, or the likely extent of their actual implementation were not assessed.*




**The history of US losses due to hurricanes over the 20th century illustrates the importance of socioeconomic factors in determining vulnerability. Since 1900, economic losses due to hurricanes have increased markedly, while deaths due to hurricanes have decreased markedly – even though there has been no significant trend in the number or intensity of hurricanes. The trends in economic losses and deaths are explained primarily by socioeconomic factors. The decline in deaths reflects the importance of improved forecasts, warning systems, and emergency preparedness measures, an important set of adaptation measures to extreme weather events. The increase in property losses reflects the increasing concentration of valuable property and infrastructure in low-lying coastal regions in the path of hurricanes. Many more people and much more property are now located in harms way, and while we have grown much better at protecting the people from hurricanes, we cannot protect the property.**

# OUR CHANGING NATION

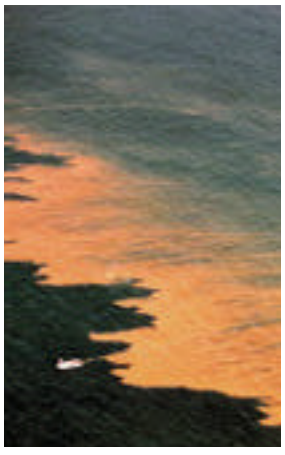
## Multiple Stresses, Surprises, and Advancing Knowledge

*Past environmental suprises have included the appearance of the 1930s drought, and the 1980s appearance of the Antarctic ozone hole. Potential large-consequence surprises present some of the more worrisome concerns raised by climate change, and pose the greatest challenges for policy and research.*

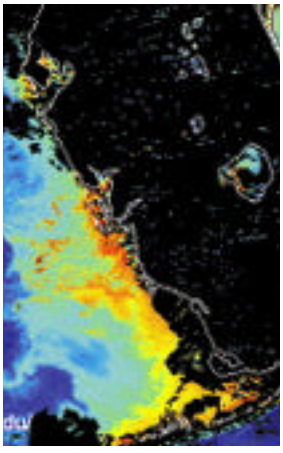
Climate change will occur together with many other economic,technological,and environmental trends,which may stress the same ecological and social systems and interact with climatic stresses. Human society has imposed various stresses on the environment,at diverse scales, for centuries. Over the 21st century some non-climatic stresses will likely increase (such as loss of habitat) while others decrease (such as acidifying pollution); climate change is likely to compound some non-climatic stresses and mitigate others. Systems that are already bearing multiple other stresses are likely to be more vulnerable to climatic stress. This applies to communities and managed ecosystems,such as marginal agriculture or resource-based communities suffering job loss and out-migration. It also applies to natural ecosystems,whose capacity for adaptation is,in general,likely to be much more limited than that of human communities. Although the central importance of considering interactions between multiple stresses is clear, present tools and methods for doing this are limited;this limitation points to an important set of research needs.

Many climate changes and their impacts will likely be extensions of trends that are already underway, and so are at least partly predictable,but some are not. We often expect natural and social systems to change and respond continuously:push the system a little,and it shifts a little. But complex climatic,ecological,and socioeconomic systems can sometimes respond in highly discontinuous ways:push the system a little more,and it might shift to a completely new state. Such discontinuities or surprises can be seen clearly after they happen,and attempting to explain them often generates important advances in our understanding,but they are extremely difficult to predict. Several possible surprises and discontinuities have been suggested for the Earth's atmosphere,oceans,and ecosystems. Still more potential for surprise arises from the intrinsic unpredictability of human responses to the challenges posed by climate change. Even if the probability of any particular surprise occurring is low (which might not be the case),potential surprises are so numerous and diverse that the likelihood of at least one occurring is much greater. We

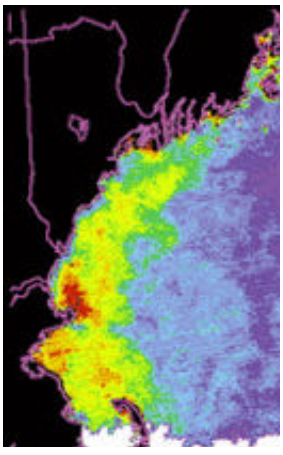
Harmful Algal Blooms



California



Florida



New England

**The increase in harmful algal blooms along nearly all US coastlines may be an ecological effect of multiple environmental stresses. The number and intensity of toxic algal blooms, the areas and number of fisheries affected, and the associated economic losses have all increased in recent decades.**

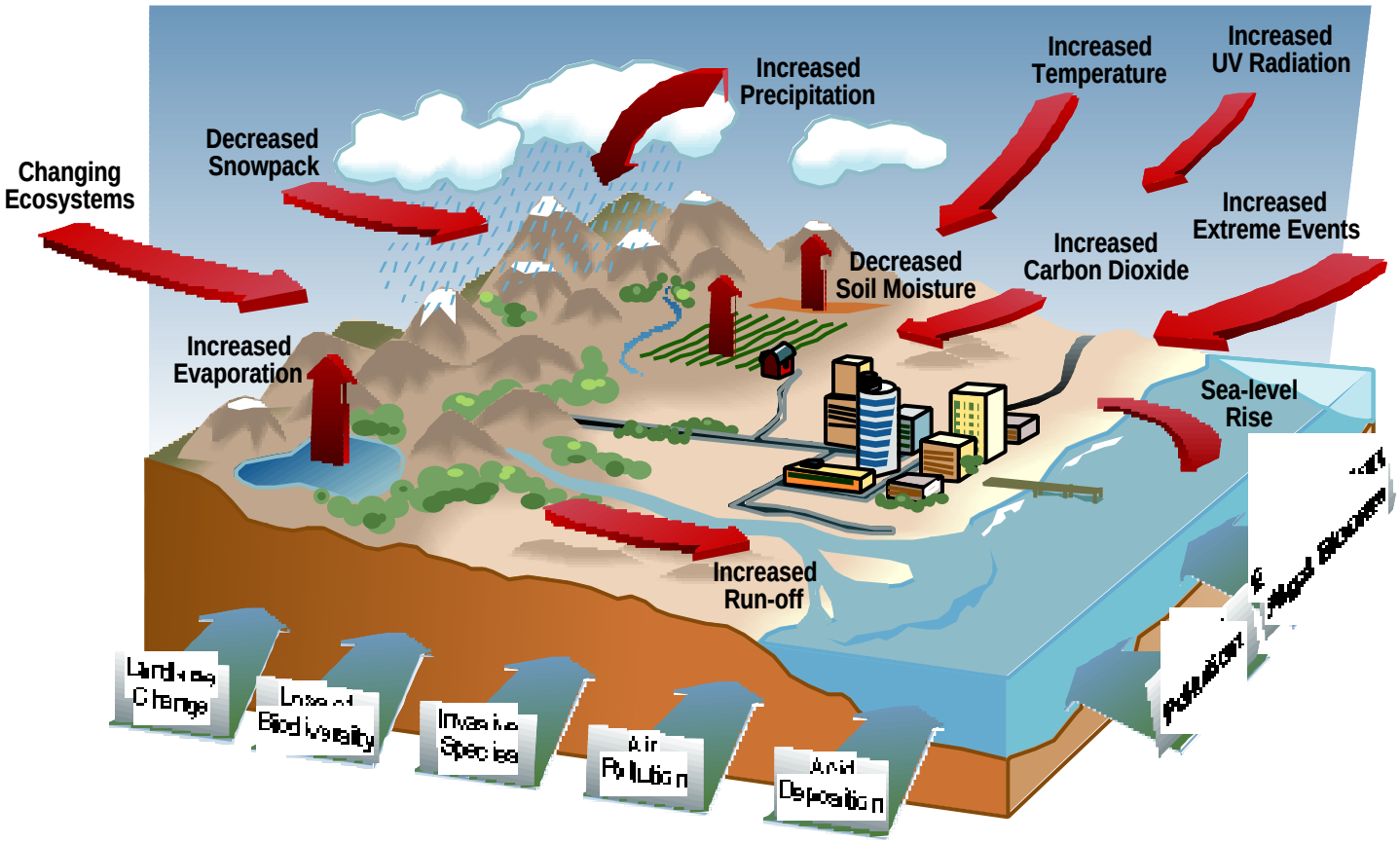
**The causes are not yet clear, but are suspected to reflect combined effects of pollution, excess nutrient input, transport of toxic species, and climate conditions. Red tides, which can render shellfish poisonous, are one type of toxic algal bloom that appear to increase with warmer ocean temperatures.**

have been surprised by environmental and socioeconomic changes many times. Examples of past environmental surprises include the appearance of the 1930s drought,and the 1980s appearance of the Antarctic ozone hole. Potential large-consequence surprises present some of the more worrisome concerns raised by climate change,and pose the greatest challenges for policy and research.

Surprises are inherently unpredictable. But two broad approaches can help us prepare to live with a changing and uncertain climate, even considering the possibility of surprise. First,some of our assessment effort can be devoted to identifying and characterizing potential large-impact events, even if we presently judge their probability to be very small. Second,society can maintain a diverse and advancing portfolio of scientific and technical knowledge,and policies that encourage the creation and use of new knowledge and technology. This would provide a powerful foundation for adapting to whatever climate changes might come.

*Continually advancing knowledge and technology, and the social, economic, and policy conditions that support them, provide a powerful foundation for adapting to whatever climate changes might come.*

## Climate Change and other Environmental Stresses




**Although climate change has multiple linked impacts, climate change is itself just one of many forms of change underway in the global environment, connected in complex and uncertain ways. The figure illustrates several of the effects of climate change and several other forms of environmental change underway. Developing tools and methods to assess the impacts of climate change in the context of other environmental changes will be a high priority for future assessments.**