2A.4 **KEY NATIONAL IMPACTS**

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1. Introduction

Last June, the 188 page report *Global Climate Change Impacts in the United States* (Karl et al., 2009) was released. The full report is available in book form, published by Cambridge University Press, or electronically from www.globalchange.gov/usimpacts. The report has 10 key findings. Three of these findings are covered by other AMS Extended Abstracts presented as part of the session discussing all aspects of this report. The remaining 7 key impacts related messages span the sectors of water resources, energy supply and use, transportation, agriculture, human health and society, and are presented here. Note that the report was prepared with a lay audience in mind, so temperature change is expressed in degrees Fahrenheit rather than Celsius.

2. Key Messages

2.1. Widespread climate-related impacts are occurring now and are expected to increase.

Climate changes are already affecting water, energy, transportation, agriculture, ecosystems, and health. These impacts are different from region to region, as illustrated by Figure 1, and will grow under projected climate change.

2.2. Climate change will stress water resources.

Water is an issue in every region, but the nature of the potential impacts varies as shown in Figure 2. Drought, related to reduced precipitation, increased evaporation, and increased water loss from plants, is an important issue in many regions, especially in the West.

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Floods and water quality problems are likely to be amplified by climate change in most regions. Declines in mountain snowpack are important in the West and Alaska where snowpack provides vital natural water storage.

2.3. Crop and livestock production will be increasingly challenged.

Agriculture is considered one of the sectors most adaptable to changes in climate. However, increased heat, pests, water stress, diseases, and weather extremes will pose adaptation challenges for crop and livestock production.

Many crops show positive responses to elevated carbon dioxide and low levels of warming. But the effects of elevated CO_2 on agriculture can be complex in part because, as illustrated in Figure 3, elevated levels of CO_2 also impacts weed growth. While higher carbon dioxide levels generally cause plants to grow larger, this is not necessarily a benefit because the larger plants are often less nutritious.

2.4. Coastal areas are at increasing risk from sea-level rise and storm surge.

Sea-level rise and storm surge place many U.S. coastal areas at increasing risk of erosion and flooding, especially along the Atlantic and Gulf Coasts, Pacific Islands, and parts of Alaska. Energy and transportation infrastructure and other property in coastal areas are very likely to be adversely affected.

The impact of sea-level rise may be felt strongly during storm events as rising sea level would allow storm surge to be higher as well. Sea-level projection is an area of intense research with most recent estimates coming in higher than earlier estimates, as illustrated by Figure 4.

2.5. Threats to human health will increase.

Health impacts of climate change are related to heat stress, waterborne diseases, poor air quality, extreme weather events, and diseases transmitted by insects and rodents. Robust public health infrastructure can reduce the potential for negative impacts. But even with some adaptation measures, potential impacts such as those shown in Figure 5, can be large.

2.6. Climate change will interact with many social and environmental stresses.

Climate change will combine with pollution, population growth, overuse of resources, urbanization, and other social, economic, and environmental stresses to create larger impacts than from any of these factors alone. For example, an analysis of Figure 6 reveals that the population is growing in areas impacted by hurricanes and in parts of the arid Southwest where water resources are already stressed.

2.7. Future climate change and its impacts depend on choices made today.

The amount and rate of future climate change depend primarily on current and future human-caused emissions of heat-trapping gases and airborne particles. Responses involve reducing emissions to limit future warming, and adapting to the changes that are unavoidable. The differences in global temperature projections based on lower and higher emissions scenarios, shown in Figure 7, highlights range of possible futures.

3. Conclusions

Global climate change will impact many aspects of American life. The full report provides a more in depth assessment and is available via www.globalchange.gov/usimpacts.

4. References

Gutowski, W.J., G.C. Hegerl, G.J. Holland, T.R. Knutson, L.O. Mearns, R.J. Stouffer, P.J. Webster, M.F. Wehner, and F.W. Zwiers, 2008: Causes of observed changes in extremes and projections of future changes. In: *Weather and Climate Extremes in a Changing Climate: Regions of Focus: North America, Hawaii, Caribbean, and U.S. Pacific Islands* [Karl, T.R., G.A. Meehl, C.D. Miller, S.J. Hassol, A.M. Waple, and W.L. Murray (eds.)]. Synthesis and Assessment Product 3.3. U.S. Climate Change Science Program, Washington, DC, pp. 81-116.

Hayhoe, K., D. Cayan, C.B. Field, P.C. Frumhoff, E.P. Maurer, N.L. Miller, S.C. Moser, S.H. Schneider, K.N. Cahill, E.E. Cleland, L. Dale, R. Drapek, R.M. Hanemann, L.S. Kalkstein, J. Lenihan, C.K. Lunch, R.P. Neilson, S.C. Sheridan, and J.H. Verville, 2004: Emission pathways, climate change, and impacts on California. *Proceedings of the National Academy of Sciences*, **101(34)**, 12422-12427

Hayhoe, K., C. Wake, B. Anderson, X.-Z. Liang, E. Maurer, J. Zhu, J. Bradbury, A. DeGaetano, A.M. Stoner, and D. Wuebbles, 2008: Regional climate change projections for the Northeast USA. *Mitigation and Adaptation Strategies for Global Change*, **13(5-6)**, 425-436.

Hayhoe, K., K. Cherkauer, N. Schlegal, J. VanDorn, S. Vavrus, and D. Wuebbles, 2009: Regional climate change projections for Chicago and the Great Lakes. *Journal of Great Lakes Research*, in press.

Karl, T. R., J. M. Melilo and T. C. Peterson, eds., 2009: *Global Climate Change Impacts in the United States*. Cambridge University Press, New York, 188 pages.

Meehl, G.A., C. Covey, T. Delworth, M. Latif, B. McAvaney, J.F.B. Mitchell, R.J. Stouffer, and K.E. Taylor, 2007a: The WCRP CMIP3 multi-model dataset: a new era in climate change research. *Bulletin of the American Meteorological Society*, **88(9)**, 1383-1394.

Meehl, G.A., T.F. Stocker, W.D. Collins, P. Friedlingstein, A.T. Gaye, J.M. Gregory, A. Kitoh, R. Knutti, J.M. Murphy, A. Noda, S.C.B. Raper, I.G. Watterson, A.J. Weaver, and Z.-C. Zhao, 2007b: Global climate projections. In: *Climate Change 2007: The Physical Basis*. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor, and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, UK, and New York, pp. 747-845.

Rahmstorf, S., 2007: A semi-empirical approach to projecting future sea-level rise. *Science*, **315(5810)**, 368-370.

Smith, T.M., R.W. Reynolds, T.C. Peterson, and J. Lawrimore, 2008: Improvements to NOAA's historical merged land–ocean surface temperature analysis (1880–2006). *Journal of Climate*, **21(10)**, 2283-2296.

U.S. Census Bureau, 2002: *Population of States and Counties of the United States: 1790-2000.* U.S. Census Bureau, Washington, DC, 226 pp. <http://www.census.gov/population/www/censusdata/hiscendata.html> See <http://www.census.gov/popest/counties/> for 2008 estimates.

Walsh, J.E., W.L. Chaman, V. Romanovsky, J.H. Christensen, and M. Stendel, 2008: Global climate model performance over Alaska and Greenland. *Journal of Climate*, **21(23)**, 6156-6174.

Wehner, M., 2005: Changes in daily precipitation and surface air temperature extremes in the IPCC AR4 models. *US CLIVAR Variations*, **3(3)**, 5-9.

Wolfe, W., L. Ziska, C. Petzoldt, A. Seaman, L. Chase, and K. Hayhoe, 2007: Projected change in climate thresholds in the northeastern U.S.: implications for crops, pests, livestock, and farmers. *Mitigation and Adaptation Strategies for Global Change*, **13(5-6)**, 555-575.

Zervas, C., 2001: *Sea Level Variations of the United States 1985-1999*. NOAA technical report NOS CO-OPS 36. National Oceanic and Atmospheric Administration, Silver Spring, MD, 66 pp. <http://tidesandcurrents.noaa.gov/publications/techrpt36doc.pdf>

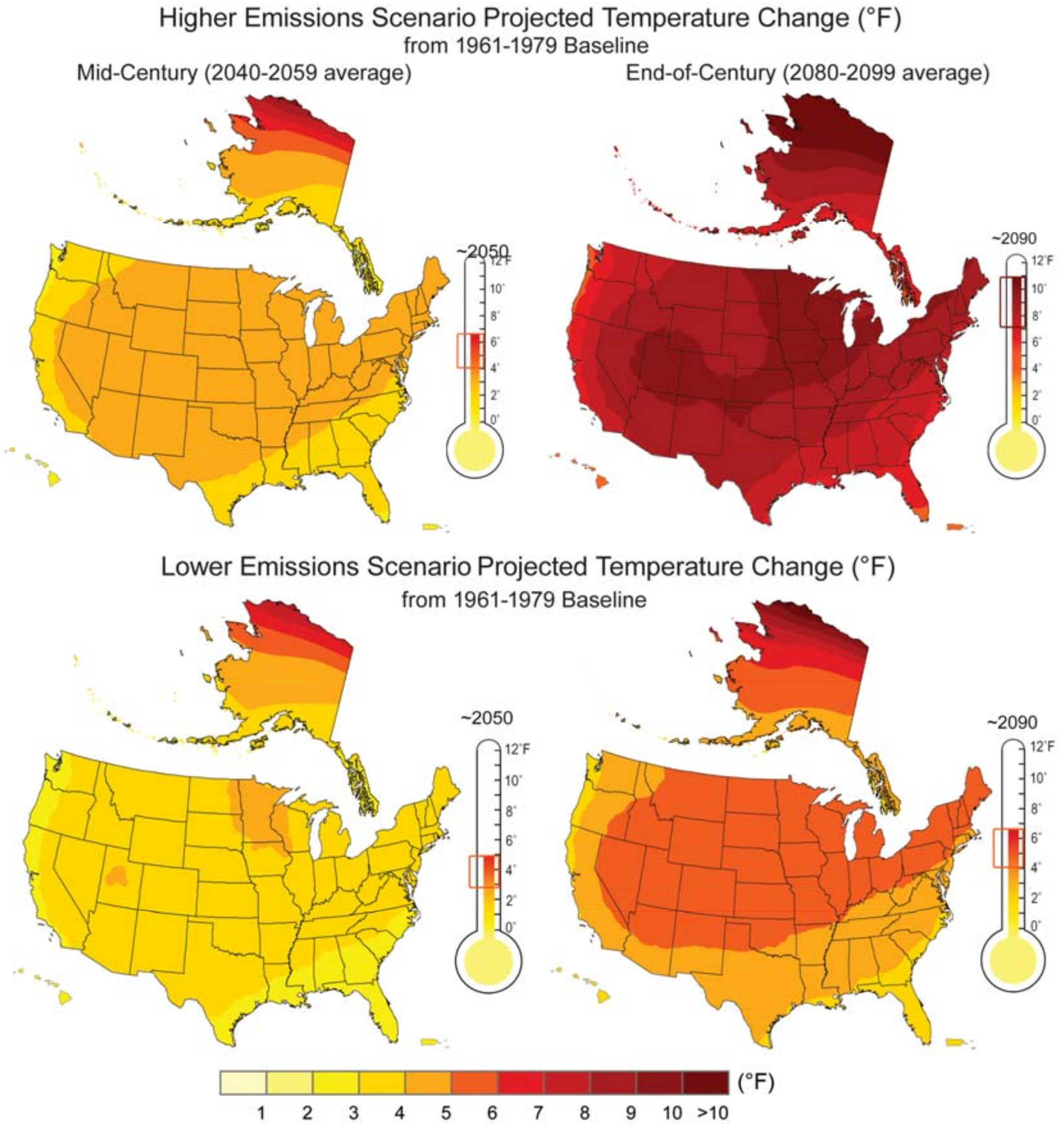

Figure 1. Projected temperature change. The maps and thermometers on this page show the projected temperature differences from conditions as they existed during the period from 1961-1979. The projected temperatures are based on results from 16 climate models for the periods 2010-2029, 2040-2059, and 2080-2099. The brackets on the thermometers represent the likely range of model projections, though lower or higher outcomes are possible. The mid-century and end-of-century maps show projections for both the higher and lower emission scenarios which correspond to IPCC SRES A2 and B1 respectively. The analysis for the contiguous U.S. was based on methods described in: Hayhoe et al., (2004, 2008) This analysis uses 16 models simulations from the WCRP CMIP3. Where models had multiple runs, only the first run available from each model was used. The Alaskan projections are based on 14 models that best captured the present climate of Alaska; see Walsh et al (2008). Caribbean and Pacific islands analyses use 15 models simulations from the WCRP CMIP3 (Meehl et al., 2007a) that were available at resolutions finer than 4 degrees (CCSM3.0, CSIRO, UKMO-HadCM3, IPSL, ECHAM5/MPI, CGCM3.1(T47), GFDL2.0, UKMO-HadGEM1, MIROC3.2 (medres), MRI-CGCM2.3.2a, CNRM, GFDL2.1, INMCM3, ECHO-G, PCM); see Wehner (2005).

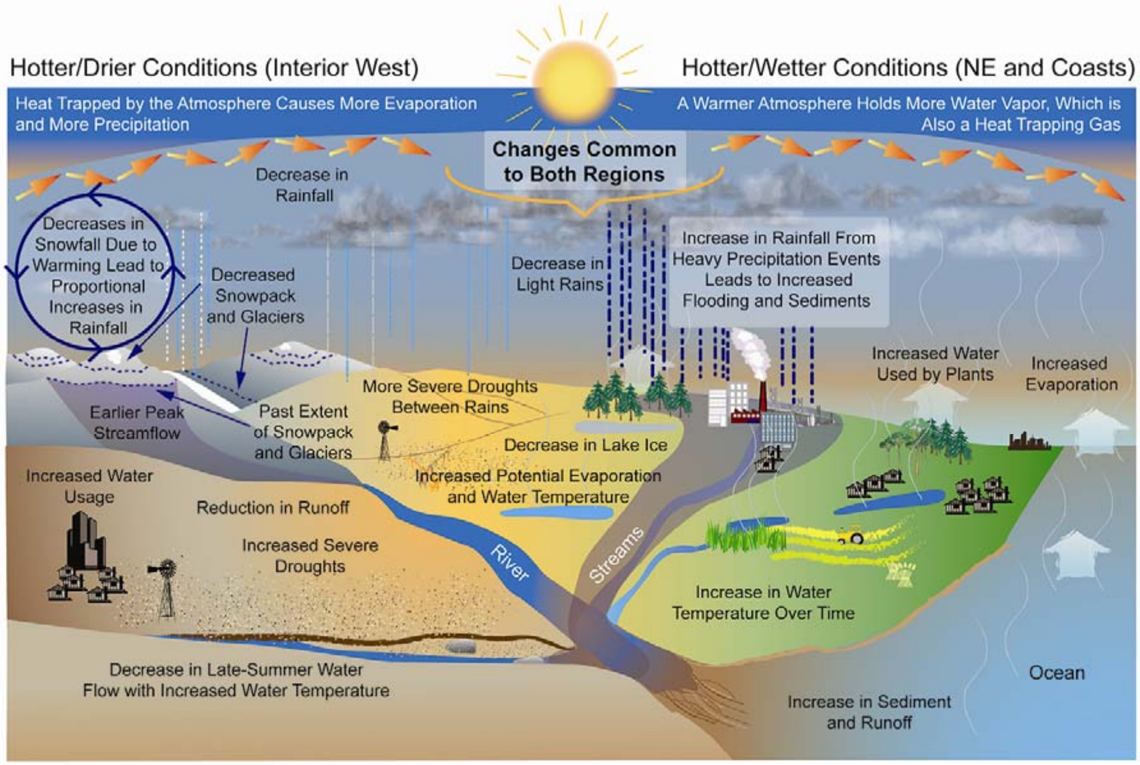

Figure 2. Projected changes in the water cycle. The water cycle exhibits many changes as the earth warms. Wet and dry areas respond differently.

Figure 3. Herbicide loses effectiveness at higher CO_2. The left photo shows weeds in a plot grown at a carbon dioxide (CO_2) concentration of about 380 parts per million (ppm), which approximates the current level. The right photo shows a plot in which the CO_2 level has been raised to about 680 ppm. Both plots were equally treated with herbicide.

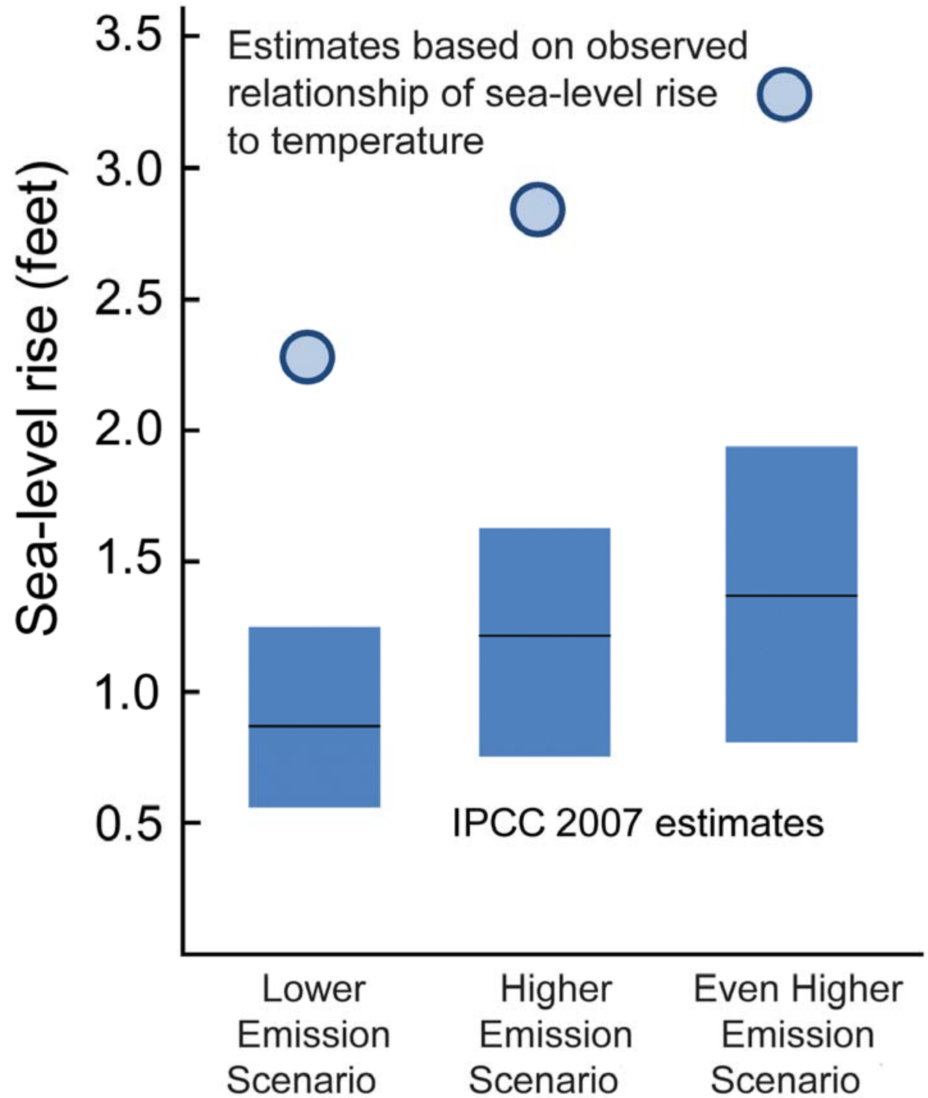

Figure 4. Projected sea-level rise. Estimates of sea-level rise by the end of the century for three emissions scenarios, IPCC SRES B1 listed as Lower, A2 as Higher, and A1FI as Even Higher. Intergovernmental Panel on Climate Change 2007 projections (range shown as bars) exclude changes in ice sheet flow (Meehl et al., 2007b). Light blue circles represent more recent, central estimates derived using the observed relationship of sea-level rise to temperature (Rahmstorf, 2007). Areas where coastal land is sinking, for example by as much as 1.5 feet in this century along portions of the Gulf Coast, would experience that much additional sea-level rise relative to the land, based on an extrapolation of NOAA tide gauge stations with records exceeding 50 years, as reported in Zervas (2001).

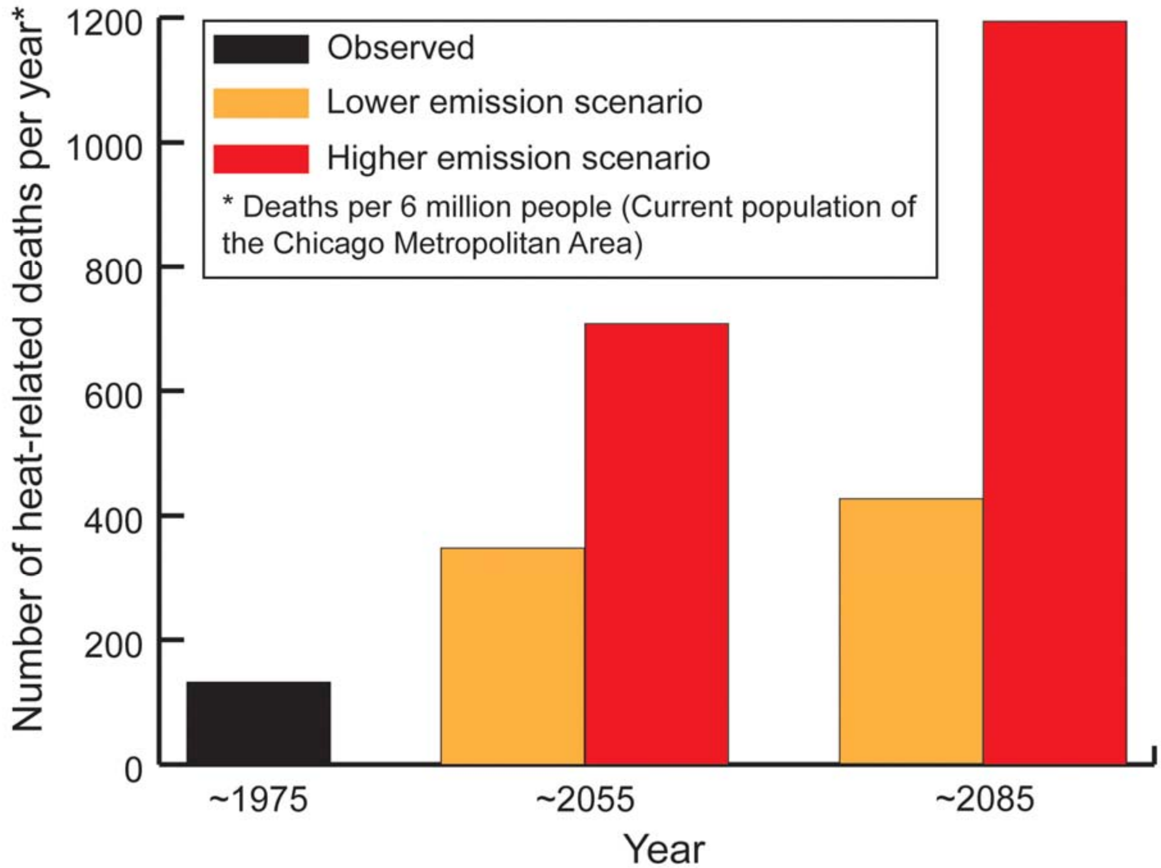

Figure 5. Projected increase in heat-related deaths in Chicago. Increases in heat-related deaths are projected in cities around the nation under the lower emissions scenario (IPCC SRES B1) and especially under higher emissions scenarios (IPCC SRES A2). This analysis included some, but not all possible, adaptation measures. The graph shows the projected number of deaths per year, averaged over a three-decade period around 1975, 2055, and 2085 for the City of Chicago under lower and higher emissions. Results are from Hayhoe et al. (2009).

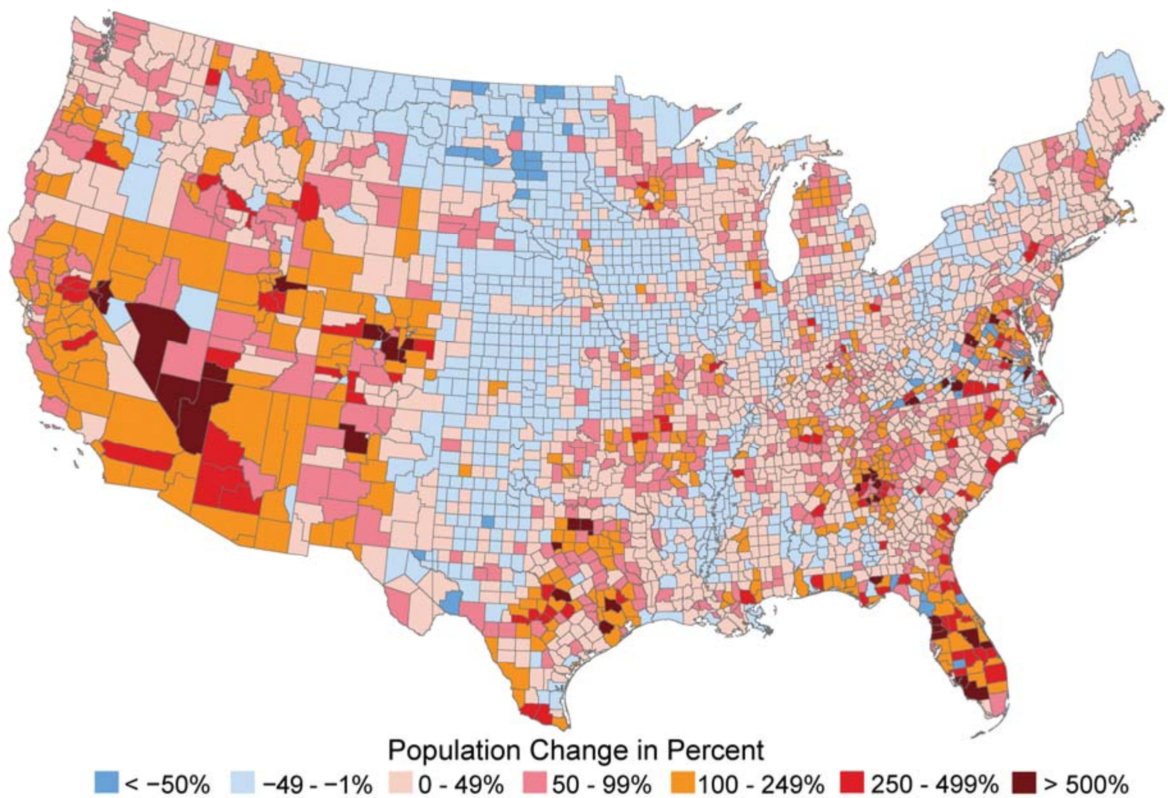

Figure 6. Change in population from 1970 to 2008 (U.S. Census Bureau, 2002). The map above, showing percentage changes in county population between 1970 and 2008, graphically illustrates the large increases in places that require air conditioning. Areas with very large increases are shown in orange, red, and maroon. Some places had enormous growth, in the hundreds of thousands of people. For example, counties in the vicinity of South Florida, Atlanta, Los Angeles, Phoenix, Las Vegas, Denver, Dallas, and Houston all had very large increases.

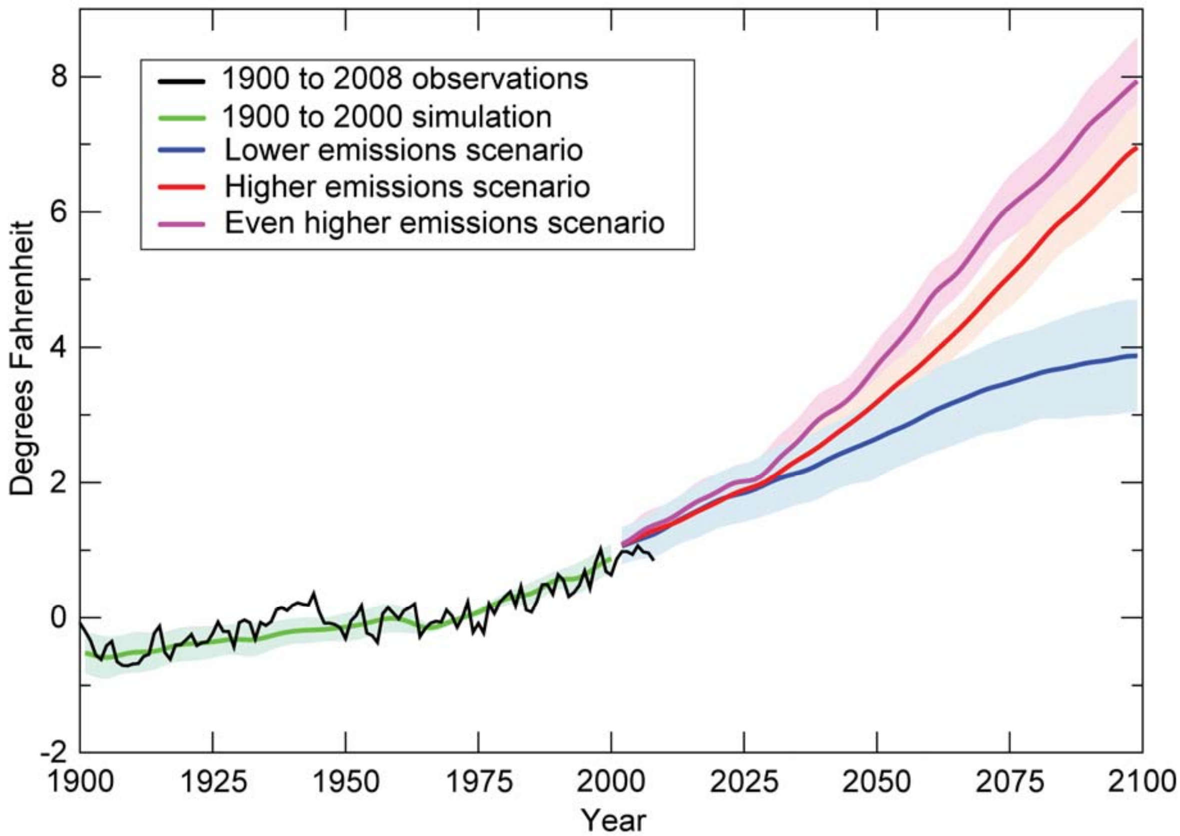

Figure 7. Observed and projected global average temperatures. Observed and projected changes in the global average temperature under three IPCC no-policy emissions scenarios. The shaded areas show the likely ranges while the lines show the central projections from a set of climate models. A wider range of model types shows outcomes from 2 to 11.5 ˚F. (Gutowski et al., 2008). Changes are relative to the 1960-1979 average. Observations are from Smith et al. (2008). Model projections are based on 15 models simulations from the WCRP CMIP3 (Meehl et al., 2007a) that were available at resolutions finer than 4 degrees (CCSM3.0, CSIRO, UKMO-HadCM3, IPSL, ECHAM5/MPI, CGCM3.1(T47), GFDL2.0, UKMO-HadGEM1, MIROC3.2 (medres), MRI-CGCM2.3.2a, CNRM, GFDL2.1, INMCM3, ECHO-G, PCM); see Wehner (2005).