Global Warming Mountaintop 'Summit': Economic Impacts on New England.

Testimony of

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To

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I thank the Chairman and the Committee for the opportunity to offer testimony on the impact of global warming on New England. For the past two decades I have focused my research on examining the Earth's climate system through the collection and analysis of ice cores from around the globe and, more recently, the analysis of instrumental meteorological data in the Northeast US. The focus of this hearing on the regional impacts of global climate change is timely and important. One of the greatest concerns of future climate change are the impacts at the local to regional scale. Changes in regional climate will affect many aspects of our lives and our communities, including our health and welfare, agriculture and natural ecosystems, water and air quality, and our economy. Climate change needs to be assessed at regional and seasonal scales to make the assessment relevant on a human scale.

Climate Change in the Northeast US over the Past Century

Over the past several years, I have worked with a group of scientists from across the Northeast to develop a series of indicators of how climate across the region has changed over the last 100 years. Changes in temperature and precipitation were determined using a subset of the United States Historical Climatology Network (USHCN) (Karl et al., 1990; Easterling et al., 1999; Williams et al., 2005), from which we calculate monthly, mean Northeast wide average temperature and precipitation (Keim et al., 2002; 2005; Wake and Markham, 2005; Wake et al., 2006a; Hayhoe et al., 2007; in review). USHCN station data represents the best available source for investigating changes in temperature and precipitation since 1900, as the stations are selected based on length and quality of data, which includes limiting the number of station changes. In addition, monthly data have undergone numerous quality assurances and adjustments to best characterize the actual variability in climate. These adjustments take into consideration the validity of extreme outliers, time of observation bias (Karl et al., 1986), changes in instrumentation (Quayle et al., 1991), random relocations of stations (Karl and Williams, 1987), and urban warming biases (Karl et al.,1988).

Mean annual temperatures averaged over the Northeast over the past 101 years (1900 – 2000) have risen 1.5 °F (0.15 °F per decade) while over the period from 1970 – 2000 annual temperatures have gone up 1.4 °F (0.47 °F per decade) at a rate three times the average for the past 100 years. More strikingly, winter (December through February) average temperatures over the last 101 years have risen 2.6 °F (0.26 °F per decade), while over the last 31 years winter temperatures have gone up 4.0 °F (1.28 per decade) (Figure 1). As a result, Boston's average winter temperature today is roughly equivalent to what Philadelphia's winter climate was 35 years ago.

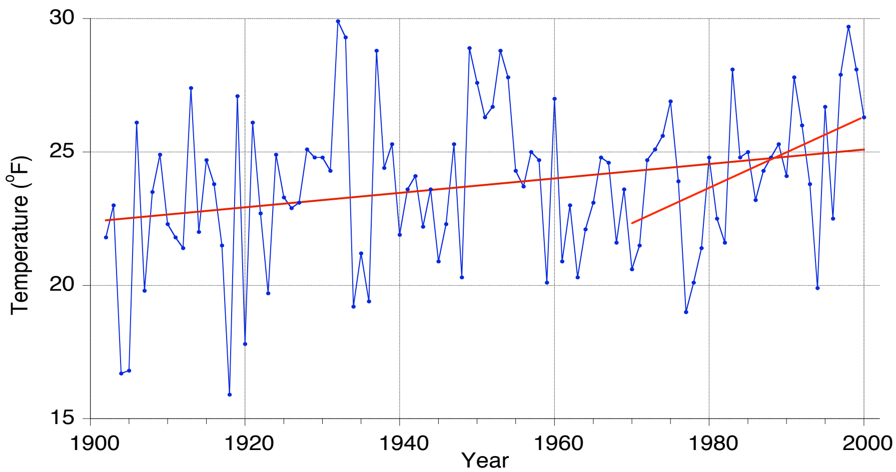

Figure 1. Mean winter (December to February) temperatures in the Northeast. Time-series represents an aerially weighted average of data from 75 USHCN stations. Red lines represent the linear trend over 101 years (1900-2000) and 31 years (1970-2000).

Overall, precipitation has increased slightly (about 10%) over the last 101 years. However, over the past 31 years (1970-2000) there has been a decrease in snowfall on the order of 10-30 inches across New England, and a larger proportion of winter precipitation is falling as rain (Huntington et al., 2004). New England stations have also experienced a decrease of 15-25 days over the entire winter in the number of days with snow on the ground. Extreme precipitation events (defined as precipitation greater than two inches in 48 hours) have increased. Ninety percent of the stations for which daily precipitation data is available for New England show an increase of 25-100% in extreme precipitation rates over the last 50 years. And this does not include the flooding rain events we experienced in May and June 2006, and April 2007.

The timing of high spring flow has also changed over the last 35 years, with spring center-of-volume flow dates (defined as the date 50% of the water has flowed passed a gauging station between 1 January and 31 May) for unregulated rivers in Maine, New Hampshire, and Vermont occurring 7-10 days earlier today compared to 30 years ago (Hodgkins et al., 2003). Ice out dates on lakes in northern New England are occurring 8 days earlier in 2005 compared to 1970 (Hodgkins et al., 2002; 2005). Lake Champlain has a 190 year record of ice-in dates. Overall, the ice forms two weeks later today compared to the early 1800s. Of the 33 times the lake has not frozen over, 80% of these events have occurred since 1950.

During the period 1965 to 2001, bloom dates for genetically identical lilac plant (*S. chinensis*, clone 'Red Rothomagensis') across the Northeast advanced abut 1 day per decade (Wolfe et al., 2005). On average lilacs now bloom 4-5 days earlier in the spring than they did in 1965.

Sea levels on the Northeast US coast continue to rise as measured at a series of tidal gauges (PSMSL, 2007). For example, in New York city, sea levels have risen 16 inches since 1850. Sea surface temperatures in the Gulf of Maine have also warmed by 1.1 ^{o}F over the past century (Smith and Reynolds, 2003).

In summary, we have investigated a wide variety of indicators of climate change for New England and the Northeast US, and all reveal that the region is warming, and that the rate of warming has increased over the last three to four decades.

Winter Recreation and Climate Variability in New Hampshire 1984 - 2006

Outdoor winter recreation is a critical economic driver for New Hampshire's four northern counties and is vital to the entire state. During the winter (December through March), almost 40% of the state's total visitor spending goes to the North Country. Almost 80% of that is spent on snow and cold dependant outdoor recreation (e.g., skiing, snowmobiling, ice fishing).

An analysis of climate variability shows that over the past two decades, there have been cold, snowy winters (1994, 1996, 2001, 2003, 2005) and warm, slushy winters (1995, 1998, 2000, 2002, 2006). Cold, snowy winters are, on average, 5 ^{o}F colder, and experience 50-60% more snowfall and 30-70% more days with snow on the ground (Wake et al., 2006b).

The difference in revenue just from ticket sales at alpine and Nordic ski areas, and from snowmobile licenses between cold, snowy winters and warm, slushy winters is striking. Warm, slushy winters result in 14% fewer alpine skiers, 30% fewer Nordic skiers, and 26% fewer snowmobile licenses. This translates into a decrease of $13 million in direct revenue from ski ticket and snowmobile registration sales, and 3,000 fewer jobs compared to cold snowy winters. Note that he $13 million is lost revenue is only for ticket sales and snowmobile licenses.

Climate Change in the Northeast over the Next Century:
The Northeast Climate Impact Assessment

How will climate across the Northeast change in the future? Results from the Northeast Climate Impacts Assessment (NECIA)(Hayhoe et al., 2007; in review; UCS, 2007) show that the climate in the Northeast that our children and grandchildren inherit depends on the decisions we make today and over the next few years about how we in the Northeast and around the globe produce and use energy. The choice of emissions pathway we follow in the near-term future matters greatly and will serve to help preserve - or fundamentally change - the natural, economic, and cultural character of the Northeast.

The Northeast Climate Impacts Assessment (NECIA) is a collaboration among team of independent scientists and the Union of Concerned Scientists to develop and communicate a new assessment of climate change and associated impacts on key climate-sensitive sectors in the northeastern United States. This study draws on recent advances in climate modeling to assess how global warming may further affect the Northeast's climate. Using projections from three state-of-the-art global circulation models (GCMs) (IPCC, 2007) (NOAA/Geophysical Fluid Dynamics Laboratory CM2.1 [Delworth et al. 2005], United Kingdom Meteorological Office HadCM3 [Pope et al. 2000], and Department of Energy/National Center for Atmospheric Research Parallel Climate Model (PCM) [Washington et al. 2000]) we compare the types and magnitude of climate changes that will result from higher emissions (IPCC A1FI scenario) of heat-trapping gases versus lower emissions (IPCC B1 scenario) in the Northeast. The first scenario is a future where emissions to continue growing rapidly, and the second is one in which society transitions onto a pathway of economic development with substantially lower emissions.

Over the next few decades, climate change across the Northeast are expected to be similar under either emission scenario and to continue the warming trends we have already experienced. These changes have already been set in motion by our emissions over the past few decades, but it takes years or decades for the climate to respond in noticeable ways.

By the middle to the end of the century, most changes projected to occur depend strongly on the emissions choices we make in the near future and carry through the rest of the century. Under the higher-emissions scenario (IPCC A1FI scenario), in which the world relies primarily on fossil fuel as the main source of energy, GCM projections for the Northeast show that by the end of this century:

- Winters could warm by 8 to 12°F and summers by 6 to 14°F.
- Cities across the Northeast could experience more than 60 days of temperatures over 90°F each summer (up from 10-15 days per summer historically). This includes 14 to 28 days with temperatures over 100°F (compared with one or two days per year historically).
- As winter temperatures rise, more precipitation will fall as rain and less as snow. By the end of the century, the length of the winter snow season could be cut in half, with only a small area in the mountains of northern New England experiencing more that 30 days of snow on the ground for the entire winter.
- The frequency of late summer and fall droughts is projected to increase significantly, with short term droughts (lasting one to three months) becoming as frequent as once per year over much of New England by the end of the century.
- The character of the seasons will change significantly, with spring arriving three weeks earlier by the end of the century, summer lengthening by about three weeks at both its beginning and end, fall becoming warmer and drier, and winter becoming shorter and milder.
- Global sea levels will continue to rise, increasing the risk of coastal flooding and damage from storm surges along the heavily developed coast in this region.

In contrast, under the lower-emissions scenario (IPCC B1 scenario), in which the world follows a pathway toward less fossil fuel-intensive industries and introduces clean and resource-efficient technologies, emissions of heat-trapping gases would peak by about mid-century and then decline. New projections for the Northeast show that smaller climate-related changes can be expected if the world follows the lower-emissions pathway - typically, about half the change expected under the higher-emissions scenario. In this case, projected changes for the region include:

- End-of-century temperature increases of 5 to 7.5°F in winter and 3 to 7°F in summer.
- An average of 30 rather than 60 days over 90°F for most cities in the region by the end of the century, and only a few days over 100°F.
- A 25 percent loss of the winter snow season.
- A likelihood of short-term drought only slightly higher than today.
- Arrival of spring one to two weeks earlier by century's end; summer would arrive only one week earlier and extend a week and a half longer into the fall.

Under either emissions scenario, the Northeast of the future will be a tangibly different place. Additional future changes that do not show dramatic differences between scenarios include:

- Increases in the likelihood and severity of heavy rainfall events..
- Increases in winter precipitation on the order of 20 to 30 percent, with slightly greater increases under the higher-emissions scenario.

Although some changes are now unavoidable, the extent of change and the impact of these changes on the Northeast depend to a large degree on the emissions choices we in the Northeast and the world make today. The "higher" emissions scenario described here is not a ceiling on what our future emissions might be, but neither is the "lower" scenario a floor on the lowest emissions we can achieve. While actions to reduce emissions in the Northeast alone will not stabilize the climate, the region is a center of global leadership in technology, finance, and innovation. Ranked against the nations of the world, it is also the seventh largest source of carbon dioxide emissions from energy use. As such, the Northeast is well positioned to be a technology and policy leader in reducing emissions and driving the national and international progress essential to providing our children and grandchildren with a safe and stable future climate.

Additional analyses are currently under way to assess the impact of the climate changes described here on forests and agriculture, coastal and marine resources, human health, and winter recreation across the Northeast, as well as options for mitigation and adaptation. These results will be published as a collection of thirteen peer-reviewed papers (Wake et al., final review) and will be summarized in a synthesis report that will be available in July 2007.

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