CHAPTER 1

NEW ENGLAND REGIONAL ASSESSMENT

AN INTRODUCTION

By Barrett Rock

The purpose of this "*New England Regional Assessment of the Potential Consequence of Climate Variability and Change*" is to provide the general public with local examples of positive and negative impacts of both recent and future climate events. Our regional climate has changed over the past century and the changes are likely to intensify over the 21st century. This report also provides examples of local strategies that may be necessary if the current climate trends continue. Taking a local view of the potential impacts that a changing climate may have on the New England region (including upstate New York) is an important first step in identifying local needs and coping strategies, improving public understanding, and identifying local and regional issues that need further study.

One way of assessing the impact of potential change in climate conditions for the New England region is to identify the current stress factors (climate-related or otherwise) impacting the region today. By looking, sector by sector, at the current stressors, one can better evaluate future climate impacts by asking the question "How would a change in climate (warmer, wetter) influence these sectors in the future?" We also offer appropriate coping strategies useful in dealing with the impacts of climate change if it occurs, and identify areas where more information would be needed to better understand impacts and how to adapt.

This assessment of the current and potential future impacts of climate change on the New England region has been conducted as part of a larger National Assessment effort, entitled "*Climate Change Impacts on the United States – The Potential Consequences of Climate Variability and Change.*" The National Assessment was mandated in 1990 by the U.S. Congress, and has been coordinated and conducted by the U.S. Global Change Research Program (USGCRP), a multi-agency effort, in response to a request from the President's Science Advisor. The National Assessment Overview document was published in December 2000. The New England Regional Assessment (NERA) was initiated in 1997, and the findings of this three-year effort are presented in the following chapters.

Developing a local perspective is important. One of the suspected culprits in the climate change debate is the emission of man-made greenhouse gases, and people assume that these greenhouse gases come from industrial sources located in mid-western states, and thus, are beyond regional control. In addition, a common view is that global warming is

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global in scale and it is not obvious to the average person how local action could have any impact on such a large-scale problem. Finally, many citizens of the New England region may think that global warming might not be so bad, since few other than winter sports enthusiasts would mind milder winters and longer growing seasons. This NERA Final Report has identified climate change impacts on the New England region that go well beyond the effect on human comfort. Climate change, if it occurs as projected, will fundamentally change both the character and the quality of life of the New England region; and thus, these potential changes must be seriously considered and action, if appropriate, must be at the local level.

To generate the New England Regional Assessment Final Report, we have directly involved regional experts/stakeholders as active participants and contributors in discussions of climate change and its potential impacts on the region. Regional issues were identified by participants during the regional assessment workshops. The Regional Assessment Team and Steering Committee (see Appendix A) have prioritized the regional issues and identified important regional Sectors (Forests, Water Relations, Human Health, and Agriculture) considered to be especially sensitive to climate variability.

The key issues identified by stakeholders are illustrated using relevant case studies in each of the Sector Chapters. In order to be included, each key issue or case study needed to meet three criteria: (1) they are important to the New England region; (2) they exhibit a clear connection to either physical or chemical climate impacts; and (3) each case study needed to be well-documented and thoroughly-understood, based on existing data. The key regional issues and illustrative case studies are presented in Table 1.1 below.

The New England Regional Assessment is available in two versions. The NERA Final Report is published in a detailed version, subjected to scientific peer review and entitled the Foundation Document. A much shorter version, called the Overview Document, contains the key points and major highlights of the NERA Foundation Document. Both are available to the general public.

TABLE 1.1
Key issues and relevant case studies presented in Chapters 5 (Forest Resources), 6 (Water Resources) and 7 (Human Health).

Key Issues	Case Studies
Air Quality	Forest Health Impacts (ground-level ozone) – Chapter 5 Human Health Impacts (Hiker Health Studies) – Chapter 7
Seasonal Dynamics	The Maple Syrup Industry – Chapter 5 The Effects of Warming on Snow – Chapter 6 Climate Impacts on Lyme disease – Chapter 7 The Relation Between the Winter NAO and Streamflow – Chapter 6 Species Migration – The Loss of Sugar Maple in New England – Chapter 5
Extreme Weather Events	The 1998 Ice Storm Damage – Chapter 5 The 1960's Drought – Chapter 6

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Important Climate Change Concepts for the New England Region

The New England region is dominated by ever-changing weather and physical climate, and residents have come to expect to be able to "work around" their weather. They also expect their weather forecasts to be reasonably accurate, and their weather predictable. Recent weather-related events have raised public awareness that the "typical" New England weather may be changing, as evidenced by recent mild winters, changing seasonal patterns (earlier springs and later falls), and what seems to be an increasing occurrence of extreme weather events (heavy rains and flooding of October 1996 and June 1998, ice storms in January 1998, and the summer droughts of 1995 and 1999).

Some basic concepts underpin our current understanding of New England's weather (day-to-day and week-to-week patterns of temperature, precipitation, and cloud cover) and climate (longer-term seasonal to decadal weather patterns). To more fully appreciate the potential climate change impacts on the region, these basic concepts are discussed below.

- **New England is Down-wind From the Rest of the Country**
  As we have come to know from watching the evening weather on TV, high and low pressure systems, storms and associated precipitation patterns move rapidly from west to east across the United States (Figure 1.1). Weather affecting the west coast and mid-west soon affects the New England region. We are in the unenviable position of being down-wind from the rest of the country and parts of Canada. Our position places us in the path not only of the weather from the rest of the country, but, due to long-distance transport,

Major Storm Patterns for the U.S.

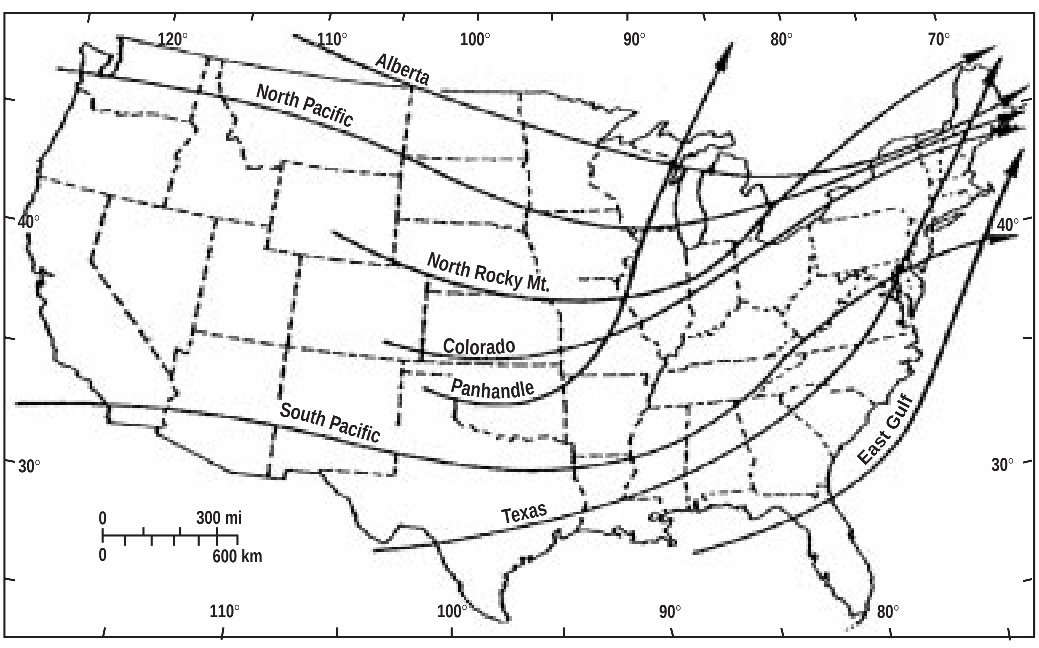

FIGURE 1.1
A plot of the major storm tracks for the United States, showing the pattern of continental weather phenomena and airborne chemical pollutants across the New England region.

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also in the path of air pollution from upwind. It has been said that New England is the tail pipe for the United States.

- **Climate Change Refers to both Physical Climate and Chemical Climate Change**

It is important to recognize that the term “climate” can refer to both physical climate (temperature, precipitation, and cloud cover) and chemical climate (including the chemical composition of the atmosphere and precipitation). Changes in the regional chemical climate are well know to the public, resulting in changes in air quality and the acidity of rainfall, snowfall, and cloud chemistry. Public concern is high for the potential impacts of ground-level ozone (smog) on both the environment as well as on human health, and the New England region is well-known for the acid rain which continues to be a problem for high-elevation lakes and forests.

Because the two types of climates are interconnected, a change in one may lead to a change in the other. Hot summer days are known to be conducive to the formation of elevated levels of ground-level ozone or smog. This smog results from the interaction of nitrogen oxides (NO_X - produced largely from automobiles), and volatile organic compounds (VOCs which in New England often come from natural sources such as forests) in the presence of sunlight (see Figure 1.2). In addition to smog, emissions of sulfur dioxide (SO_2) and NO_x from the combustion of fossil fuels can combine with cloud moisture to form acidic cloud and precipitation chemistry (sulfuric acid - H_2SO_4 and nitric acid - HNO_3 respectively). In general, SO_2 is produced in the combustion of coal or fuel oil, often in the process of generating electricity, while NO_x is produced when atmospheric nitrogen and oxygen are combined by contact with hot surfaces, such as automobile exhaust systems.

- **Physical Climate and Chemical Climate are Connected**

When we think of climate change it is only natural to think of physical climate factors such as temperature and rainfall. It is important to realize that physical climate factors have an influence on the chemical climate as well, in the form of changing air quality.

In July of 1997 the Environmental Protection Agency (EPA) implemented a new National Ambient Air Quality Standard (NAAQS) for ground-level* ozone pollution (SMOG). With the previous standard, a 1-hour average value equal to or greater than 0.125 ppm (125 ppb) of ozone was

* Ground-level ozone, a component of SMOG, should not be confused with the ozone layer in the stratosphere. Stratospheric ozone naturally occurs and acts as a filter for ultraviolate (UV) radiation, protecting life on Earth’s surface. Ground-level ozone is harmful to living systems and is anthropogenic in origin.

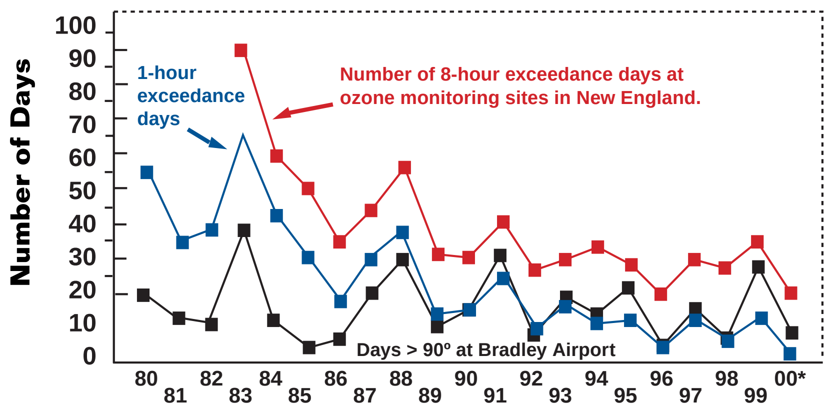
FIGURE 1.2
The relationship between NO_X, VOCs, temperature, sunlight and the formation of ground-level ozone.

This tells us that there is a strong connection between physical climate change and chemical climate change.

considered an exceedance. The new standard is more stringent and measures ozone concentrations over an 8-hour average and cannot exceed 0.080 ppm (80 ppb).

Figure 1.3 shows the number of 1-hour (.120 ppm) and 8-hour (0.080 ppm) exceedance days, compared with the number of days the temperature was at or above 90º F, as monitored at Bradley Airport, north of Hartford, CT, for the period from 1980-1998. Clearly, the years in which there were a greater number of days at or above 90º F, were also characterized by a greater number of ozone exceedances for both the 1-hour and the 8-hour standards. The years 1983, 1988, 1991, 1993, 1995 and 1997 were characterized by such exceedances. It can also be seen that a trend toward fewer days at or above 90ºF leads to fewer exceedances over the same time period. This tells us that there is a strong connection between physical climate change and chemical climate change.

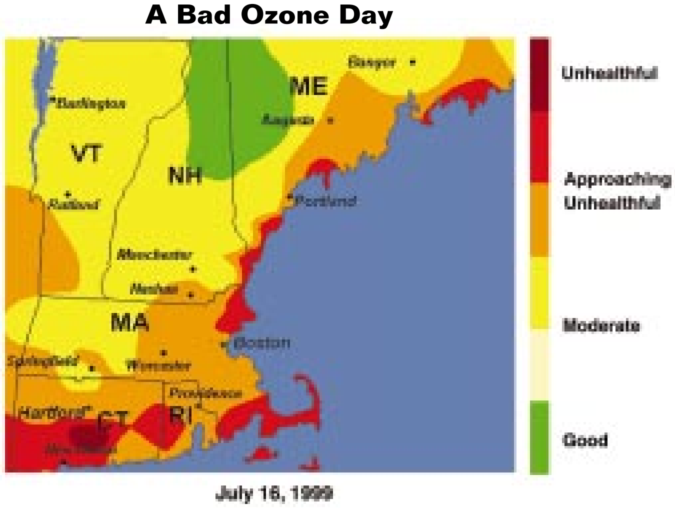
Exceedance Days vs. High Temperature Days



* 2000 data are preliminary

FIGURE 1.3 Number of 1-hr and 8-hr ozone exceedance days, as well as the number of days at or above 90ºF at Bradley Airport, Hartford, CT.

A Bad Ozone Day

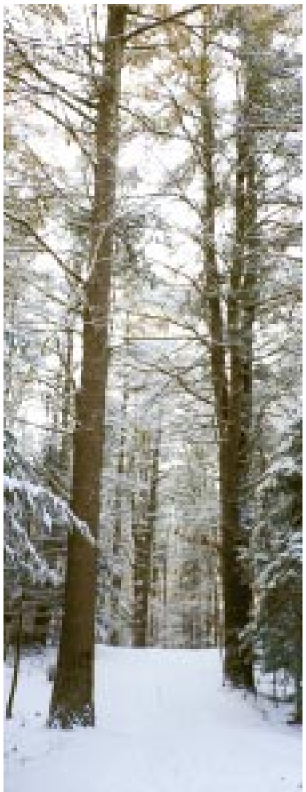


8-hour peak values

FIGURE 1.4. A high ozone day, July 16, 1999
source: http://www.epa.gov.

Figure 1.4 is a regional map for July 16, 1999, one of the worst ground-level ozone days of that year. The map is based on an interpolation of the actual maximum 8-hr average ozone concentration values at approximately 200 ground-level ozone monitoring sites from Maine to North Carolina. As can be seen in this regional portion of the overall map, unhealthful levels of ozone (8-hour concentrations of ozone above 80 ppb) occurred throughout much of the New England region. The highest ozone concentrations are commonly associated with urban centers or heavily traveled transportation corridors.

Wood represents atmospheric CO_2 stored in a stable form that is no longer able to function as a greenhouse gas.



- **The Forests of New England Sequester Carbon**

  Recent studies have shown that forests store (sequester) large amounts of carbon in the form of both structural and functional carbohydrates. Wood is composed of several types of structural carbohydrates (including cellulose and hemicellulose), along with other complex chemical compounds derived from metabolism of atmospheric carbon dioxide (CO_2).

  Although the forests of the New England region currently store 20 million metric tons of carbon per year, it is significant to understand that poor air quality adversely impacts potential photosynthetic capacity, especially in sensitive species. If air quality can be improved for the region, wood production (carbon sequestration) would increase. Reducing CO_2 and NO_X emissions, by improving gas mileage and reducing automobile traffic, would effectively improve the carbon sequestration capabilities of regional forests.

- **Why Climate Models are Used**

  The models used in this regional assessment provide dramatically different projections of scenarios. Both the Canadian General Circulation Model (CGCM1) and the Hadley Climate Model (HadCM2) were selected for several reasons, including the fact that they would provide the public with a reasonable range of scenarios or "what if" projections about future climate patterns. These models were considered robust enough to be tested at a regional scale. Since all General Circulation Models differ one from another on the basic assumptions made for producing future projections, it was decided to present two models which were considered to be based on the most reasonable assumptions.

  Thus, it is important to understand that just because these models present different scenarios, there is no reason to disregard either or both. They were selected specifically because they give different scenarios, and in the process suggest two possible "what if" futures for the region. By considering a reasonable range in "what if" scenarios, we are better able to develop possible adaptation strategies for the future. Although the two models provide two different projections, both project significant warming by 2090 (approximately 6^o F or 3.1^o C suggested by the Hadley Model; 9-10^o F or 5.3^o C by the Canadian). In either case, a 6-10^o F warming over the next 100 years would represent an unprecedented warming in such a short time, based on historical data. The two models also differ in their projections of precipitation, with the Canadian Model suggesting a slight increase in precipitation (10%) by 2090, but also projecting significant periods of drought, while the Hadley Model projects nearly a 30% increase in precipitation over the same time period. The New England we know today will not be the New England of 2090 if either model scenarios becomes a reality.

- **A Few Degrees is a Big Difference**

  The projections of a 6-10^o F (3-5^o C) warming in the next 100 years may not seem to be very significant, since tomorrow is likely to be at least 6-10^{o}F warmer or colder than it is today. A few degrees, either Celsius or Fahrenheit, doesn't seem to be that big a difference. However, it is very important that we understand what a few degrees in global or regional average temperature means in terms of climate. Approximately 20,000 years ago, parts of the New

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England region were under nearly 2 miles of ice. At that time, the northern hemisphere of Earth was experiencing a period of maximum glaciation. Within 1,500 to 2,000 years, the region had entered a period of warming known as an interglacial period. The current climate conditions today are very similar to those conditions characterizing the beginning of the interglacial period. The global average temperature difference between the last glacial maximum (2 miles of ice) and the current interglacial period is only 10-12^{o} F (5-6^{o} C)!

As an illustrative example of the difference that a change in climate of just a few degrees can make, a comparison of Boston is made with cities from other parts of the United States. The "normal" Boston, MA monthly average temperature for the 30-year period is 51.3^{o} F. Using the two climate model scenarios, we can look for cities that are, on average, 6^{o} F warmer (the Hadley model projection for 2090) and 10^{o} F warmer (the Canadian model projection) than the present conditions in Boston. If a 6^{o} F warming occurs over the next 100 years, Boston's "normal" temperature would be more like today's Richmond, VA (57.7^{o} F). If a 10^{o} F warming occurred for the region as the Canadian model projects, Boston's temperatures would be similar to those in Atlanta, GA (61.3^{o} F).

Of course, there is much more to climate than simply the temperature, but these comparisons are useful in relating the impact of just a few degrees increase in average temperature in the future. One can only imagine what would become of our ski industry, the maple syrup industry and our fall colors, if Boston becomes more like Richmond, VA or Atlanta, GA.

- **Uncertainties about the future should not result in inaction**

It is important that we recognize the great regional variability and unpredictability in attempting to forecast future regional climate trends. Certainly, using a global model "down-scaled" for use as a regional model is not the ideal way to do this. One of the key findings of the NERA effort is that such regional models, which take into account local geography, topography, land cover conditions, etc., are sorely needed. Until such regional models are available, the down-scaled Global Climate Models such as the Canadian and Hadley are the best that we have to work with.

The biggest uncertainties about future climate projections are not due to model failings, but rather in our inability to predict future levels of greenhouse gases (CO_2, CH_4, and others), the cooling effects of sulfate aerosols from both human and natural sources, as well as other forcings (solar output, land cover change, etc.). Since we can't control the natural forcings, we need to address those things that we can control (greenhouse gas emissions and land cover change).

Finally, we make informed decisions to protect valuable items (our homes, car, and possessions) by purchasing insurance policies. We buy fire insurance on our homes, even though the likelihood of our home burning down is very small. We buy such insurance, "just in case." We make medical decisions based on uncertainties – removal of a "suspicious" lump is a common medical practice, "just in case." We make such important decisions often based on far greater uncertainties than we have about the likelihood of climate change in the future. We need to take the same approach with confronting future climate change, "just in case."