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Growing Season Parameter Reconstructions for New England Using Killing Frost Records, 1697–1947

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and
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MAINE AGRICULTURAL AND FOREST EXPERIMENT STATION
University of Maine

Growing Season Parameter Reconstructions for New England Using Killing Frost Records, 1697-1947

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FOREWORD

Bulletin 846 brings together the results of data collected over the past 20 years. It is presented for its possible use as a tool in agricultural planning in state departments of agriculture and state universities. It is the first of a series of bulletins that will provide data on measurable aspects of climate in the northeastern United States. It is hoped that these data will be useful to persons studying climate change, as well as the impact of climate on human activity.

The most salient fact in this publication is the high degree of climate volatility as seen in the length of growing seasons and the related fact that in New England this volatility increased as one went north and west in the region. The lack of consistency in growing season length, however, remained an issue in people's minds even in more favored areas. Nevertheless, New England, especially to the north and west, is a marginal area for agriculture. This is especially true for those aspects of agriculture in which a relatively long growing season is needed.

The authors of this bulletin expect to publish another five bulletins with data from this region which will enhance our knowledge of the climatology of this area. The data behind these bulletins is immense. The current bulletin, for example, is based on some 27,000 data points.

There will be some users of this data who will be interested in more details than can be presented in the current form. We expect to create a World Wide Web site where a more detailed look at the data will be possible. Thus, users who wish to know the locations within a climate zone that where used to determine the growing season lengths will be able to obtain that data through the internet.

Others who wish to pursue the detailed study of an individual zone will be afforded an opportunity through the net materials. For this bulletin, however, this level of data collection is available in Maine Agricultural and Forest Experiment Station Miscellaneous Publication 731—New England Killing Frost Records by Zone. This publication is available upon request.

The data used has been scrutinized with the highest degree of accuracy that we are able to present. We will be happy to hear from readers who have other data that bear on this subject. We are continuing to supplement our database, and those persons who have additional material are asked to send it, preferably in an exact copy of the original document, to either of the authors.

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Dedicated to the late B. E. Dethier

For his scholarly friendship and assistance in the pursuit of knowledge

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PREFACE

In 1980 when the Experiment Station published our first research results (Bulletin 771), we had no idea that it would take another fifteen years before a second one would appear. Our intention then as now was to study the inter-relationships between people and their natural environment with particular emphasis on global change, climate, and agriculture. As researchers with a keen interest in both human historical experience and the intricacies of nature, we have focused on the past in order to better understand the present and the future.

Such broad-based study requires the participation of a diverse group of individuals and holding such groups together is not always easy. Such was the case with our project, as many treasured colleagues have come and gone since the late 1970s when we first gathered to lay our plans. The portion of our work concerning reconstruction of New England climate is finally drawing to an end and, we hope, over the next several years, to keep the promise we made in our first publication to produce a series of works based upon our researches. This bulletin is the first of these publications.

For the farmer in marginal climate locations, both past and present, the growing season is central. Success or failure is often defined by the length of the season, the weather that occurs during it, and the timing of certain natural events. The farmer's job is to make decisions based on his or her experience with the natural, physical parameters of the geographic locale. The more experience farmers have the better they are able to anticipate what action is needed to protect their crops. This maxim is as true today as it was nearly 400 years ago when early European settlers began to plant and sow on New England's shores. However, every so often nature changes the rules! Just when we think we know how to anticipate what is normal and what is not, our natural environment changes. What were considered centrury floods or droughts suddenly occur every two or three years. Our frame of reference is destroyed and we are unable to make necessary decisions with the same confidence that we once could. Should we doubt that this can happen, we have only to visit with the farmers of the Missouri and Mississippi valleys who recently have been visited by two one-hundred-year floods in the space of four years.

Our knowledge and ability to anticipate what will happen is derived from our personal experience and that of others who came before us. For the weather, farmers rely on the federal government or private meteorological forecasting companies. Unfortunately the data on which these agencies base their predictions is limited in its time frame. Most climate predictions are based on data recorded between 1872 and the present when the first centralized federal weather agency, the predecessor of our NOAA Weather Service, was first organized. In human terms, this is a long time period, but in natural physical terms it is a very short one. To better understand all of the possible scenarios with which our climate can provide us, we must push this record back further into the past. Instrument record keeping in New England did not start in 1872, rather as early as 1715 when Harvard obtained its first thermometer. Weather-related observations including those on killing frosts were made and recorded even earlier. We need to find, to evaluate and to analyze these historical data, and this is what we have tried to do.

Such an undertaking as this Bulletin has required the help of many individuals too numerous to name here although a few deserve special mention. First we would like to thank Janet McVickers and Mike Ruddell who organized and checked the data for accuracy. Al Richmond and Maxine Campbell provided valuable supervision for the team of undergraduate students who entered this data into a computerized database. Mark W. Anderson has provided help and encouragement whenever it was most needed. Without the unwavering support of Harold W. Borns Jr. of the Institute for Quaternary Studies at Maine, we would never have achieved our research goals. This research and publication are also due, in great part, to the assiduous support of Emeritus Professor Geddes W. Simpson who is the exemplar of a station scientist. We appreciate the assistance of the members of the Northeast Environmental Research Group at Maine which disbanded in the mid-1980s and the Historical Climate Records Office at Northern Arizona University. As sometime members of the Northeast Climatology Research Group (NE35, later NE95) based at Cornell University, we wish to thank other members for their support and advice on our work. We remember the various meetings at Burlington, Ithaca, and Asheville very well. Finally, both of our wives have assisted in our research endeavors in numerous ways.

The staffs of a number of libraries and archives also provided invaluable aid. These include the Academy of Natural Sciences at Philadelphia, American Academy of Arts and Sciences in Boston, American Antiquarian Society, Arizona State University Libraries, Bangor Maine Public Library, Bellingham Massachusetts Public Library, Bethel Maine Historical Society, Boston Public Library, Brick Store Museum of Kennebunk, Bristol Rhode Island Historical and Preservation Society, Brown University Libraries, Connecticut Historical Society, Connecticut State Library, Connecticut Valley Historical Museum of Springfield, Dedham Massachusetts Historical Society, Dresden Maine Historical Society, Fitchburg Massachusetts Historical Society, Forbes Library of Northampton, Freeport Maine Historical Society, Harrison Maine Historical Society, Harvard University Libraries, Haverhill Massachusetts Public Library, Historic Deerfield Massachusetts Libraries, Jamestown Rhode Island Historical Society, Kennebunk Maine Free Library, Kennebunkport Maine Historical Society, Kent Memorial Library of Suffield Connecticut, Lexington Massachusetts Historical Society, Library Company of Philadelphia, Lincoln County Maine Cultural and Historical Association, Litchfield Connecticut Historical Society, Machias Maine Public Library, Maine Historical Society, Maine State Library and Archives, Massachusetts Historical Society, Mystic Seaport Museum, Nantucket Historical Association, Nantucket Maria Mitchell Association, New England Historic Genealogical Society, New Gloucester Maine Historical Society, New Hampshire Historical Society, New Hampshire State Library, New Haven Colony Historical Society, New London County Historical Society, Newport Historical Society, North Kingstown Rhode Island Free Library, Northern Arizona University Library, Old Colony Historical Society, Old Plymouth Plantations, Old Sturbridge Village Research Library, Peabody-Essex Institute, Princeton University Library, Providence Public Library, Rhode Island Historical Society, Royal Society of London, Shelburne Museum, Sheldon Art Museum, Skinner Historical Settlement, Smithsonian Institution Archives, Society for the Preservation of New England Antiquities, South Kingstown Rhode Island Public Library, Stonington Connecticut Historical Society, Strawberry Banke of Portsmouth, University of Arizona Libraries, University of Connecticut Library, University of Maine Library, University of Massachusetts Library, University of New Hampshire Library, University of Rhode Island Library, University of Vermont Library, U.S. Library of Congress, U.S. National Archives, Vermont Historical Society, Westfield Massachusetts Atheneum, Woburn Massachusetts Public Library, Worcester Historical Museum, and Yale University Libraries.

We thank the following for funding support: the National Science Foundation (ATM7908415, ATM8019514, ATM8116714, and ATM8312874), the Northeast Regional Agricultural Experiment Stations, and Associate Vice President Henry O. Hooper and Northern Arizona University's Organized Research Fund for help in providing funding for data entry. Baron would like to thank Old

Sturbridge Village for a Research Fellowship in 1990, the Association of State and Local History for a grant in 1986, the National Endowment for the Humanities for a Small Travel Grant in 1990 and NAU's Organized Research Fund for a grant in 1994/95.

Despite all of this assistance, our feet occasionally may have slipped from the correct path. For those instances, we are entirely responsible.

W.R.B.
Flagstaff, Arizona

D.C.S.
Bangor, Maine

Introductory Essay

William R. Baron

A SHORT HISTORY OF FROST RECORD KEEPING IN THE U.S.

In New England, killing frosts in the late spring and early fall mark the limits of the region's growing seasons. Over the years, farmers have tried to anticipate when to plant and when to harvest to safely prevent their crops from experiencing the harmful effects of freezing. As a hedge against failing memory, some farmers kept notes on when killing frosts occurred so that they could more readily calculate in the years to come when to sow and when to reap. Some of these notes have survived the ravages of time and are now preserved in archives and libraries across the region. Some still remain the proud possessions of later generations of the same farm families. The growing season records reconstructed for this Bulletin are based on data taken from these diaries, farm journals, notebooks, and scraps of paper and represent the observations of several generations of New England farmers.

These people were not "professional scientific" observers in the sense that we might use those words today, but they were careful observers because their livelihood and the well being of their families depended on their accuracy. During the eighteenth and early nineteenth centuries, agriculturists did not command a scientific vocabulary and shared no common definitions for terms such as "killing" frost or "growing" season. But they made up for their lack of scientific sophistication with a thoroughness of description that allows us in this century to fully understand that "September 3rd, a severe black frost that laid low all of our vines, corn and potatoes will make a hungry winter for us" meant a killing frost in the early fall. And "May 22nd, a hard frost on the lowlands that cut short our young corn there" leaves little doubt that a radiation frost of killing proportions forced a replanting of corn in valley areas. During this early time period, there were no formally organized meteorological networks, but these amateur observers often shared data and ideas with one another (Baron 1989, 1992a).

From 1818 until 1947 a series of meteorological networks organized by agencies of the federal government including the U.S. Army Surgeon General's Office, the Smithsonian Institution, the Bureau and then Department of Agriculture, the Army Signal Service, and the Weather Bureau, all predecessors of today's Weather Service, used farmers' observations of killing frosts to calculate the length of growing seasons (Guyot 1855; U.S. Weather Bureau 1915). A division of effort evolved with trained professional personnel forming a primary or first class network of observation stations supplemented by a much larger group of amateur data gathers including farmers. This organizational pattern persists to the present day (Baron 1992a; Fleming 1990).

Over time various scientific definitions were worked out. For observational purposes, first the Signal Service and then the Weather Bureau defined a killing frost as a frost "that is generally destructive of vegetation and the staple products of the locality" (U.S. Weather Bureau 1915). A growing season came to be defined as a period in which the chance of a killing frost is insignificant enough to permit profitable agriculture in nine out of ten years (Kalma et al. 1992). Various government agencies used these frost data to produce publications analyzing past frost dates and to predict the dates of future ones (Brewer 1859; Galloway 1895; Garriott 1906; Kincer 1919; U.S. Department of Agriculture 1941).

As statistical tools became more sophisticated, researchers came to realize that the definitions employed to make observations concerning killing frosts were somewhat subjective and imprecise (Ward 1925; Landsberg 1941). Therefore in 1948 the Weather Bureau redefined the frost-free or growing season as the period between the last occurrence of 0°C in the spring and the first such occurrence in the fall (Chang 1971). The definition of a freeze became an observation of 0°C recorded on a thermometer located 1.5 m above the ground in a meteorological instrument shelter (Schmidlin and Dethier 1986). Using this new database, researchers began to develop ways to predict the growing season parameters for future seasons. Reports on their work for across the U.S and Canada appeared in a series of professional journal articles and in experiment stations reports. See Table 1.

The definitional changes instituted in 1948 mark the great divide in frost and growing season studies. Present day data derived from instrument readings are not readily or easily comparable to the killing frost observations of an earlier era. Only one study listed below attempted to combine the two types of data, and the authors of that work now believe that adjusting these data into a homogeneous record presents additional difficulties not anticipated in their original research (Baron et al. 1984). Recent research concerning the impact of ice nucleation active bacteria on the supercooling of water within plant cells now makes this divide appear to be all that much more insurmountable.

Table 1. Selection of studies on growing seasons and freezes employing 0°C databases

Location	Reference
Iowa	Thom and Shaw 1958
Ohio	Pierce 1959
Oregon	Eichhorn, Rudd, and Calvin 1961
Northeast U.S.	Havens and McGuire 1961
New England	Kolega and Palmer 1961
Indiana	Schaal, Newman, and Emerson 1961
Arizona	Kangieser 1962
North Carolina	Hardy 1964
Vermont	Hopp, Varney, and Lautzenheiser 1964
Connecticut	Brumbach 1965
Louisiana	Cry 1968
Maine	Cooper and Lautzenheiser 1969
Nevada	Sakamoto and Gifford 1970
United States	Huszar 1975
Colorado	Benci and McKee 1977
Wisconsin	Moran and Morgan 1977
South Carolina	Kish 1978
Virginia	Pielke, Styles, and Biondini 1979
Alabama	Gallup 1980
Massachusetts	Baron, Gordon, Borns, and Smith 1984
Minnesota	Skaggs and Baker 1985
New York	Schmidlin and Dethier 1986
Southeastern U.S.	Suckling 1986
Florida	Waylen 1988
Saskatchewan	Waylen and LeBoutillier 1988, 1989
Ontario	Bootsma and Brown 1989
Alaska	Sharratt 1992

FROSTS, METEOROLOGY AND CROPS

Basic Meteorological Processes

Solar energy in the form of short wave radiation strikes the earth during the day and is absorbed causing the earth to heat up. Cloud cover and certain substances on the earth's surface, such as ice and snow, contribute to the reflection of some of this energy back out into space. During the night, excess heat from the earth is radiated back up into the atmosphere as long wave energy. The atmosphere radiates some of this energy back to the earth while some is lost to space. The ability of the atmosphere to radiate energy back is strongly influenced by the amount of water vapor, CO_2, and other gases that make up the atmosphere as well as the amount of cloud cover over a particular area. As the earth radiates energy, the part of the air column closest to the earth's surface cools first; thus cooling takes place from the bottom of the air column upward. Often there is turbulence or wind in the atmosphere that helps to mix the air and to make its temperature more uniform from bottom to top. However, in the absence of winds, the earth's surface cools fairly rapidly relative to the air at a given distance above the surface (Geiger 1950; Oke 1978; Hobbs 1980).

In the spring and fall when the amount of solar radiation received by the earth is less than in the summer, this cooling at the earth's surface can lead to the formation of frost on plants as air temperatures drop to or below 0°C. Frosts of this sort are called radiation frosts and occur on calm, clear, and dry nights. During such radiation frosts, thermometers situated near the earth, as well as those at various elevations above it, display data showing clear evidence of strong temperature inversions with warm air overriding the cooler air at the surface (Kalma et al. 1992; Oke 1978). As a part of this radiative process, cool air pools and flows along the earth's surface from higher elevations to lower ones. Thus locations in valleys and various other sorts of geologic depressions are more prone to experience radiation frosts than locations on hill tops (Thompson 1986; Tabony 1985; Bootsma 1976; Hocevar and Martsolf 1971; Bergen 1969, 1971/72; Taylor 1967). These frosts often are the product of meteorological conditions affecting relatively small geographic areas. In some instances, regions can have their growing season lengths affected by large bodies of water up wind from them (Kopec 1967).

A second type of frost condition is called advective. Advective frosts are the product of major large-scale meteorological processes that cause an influx of cold air from polar regions. These bodies of cold air, usually in the form of high pressure areas, move along the track of the circumpolar vortex, which is closely associated with the jet stream. Advective frosts are often associated with moderate to strong winds and a well-mixed cool atmosphere. They affect fairly large geographic areas, bring temperatures often well below 0°C, and have their greatest impact in the higher latitudes and at higher elevations (Kalma et al. 1992; Oke 1978).

The most damaging frosts are produced by a combination of both advective and radiative conditions. In these situations a cool polar air mass moves over a region producing an advective frost. After the cool air mass moves on, there is a general clearing accompanied by decreasing winds and little mixing of the air column. These conditions produce a radiative frost (Kalma et al. 1992).

Frost and Crop Plants

Most major agricultural crop species are frost-sensitive plants. Under field conditions, the water in the cells of these plants often freezes at between -2°C and -5°C (Lindow 1983a). At these temperatures two types of freezing are possible in plants. The first type is extra cellular freezing in which water outside of the plant's cell wall freezes at temperatures very close to 0°C. This process drains water out of cells toward the plant's surface increasing the solution concentrate within the individual cells, which serves to reduce the freezing point of the cells. As a result, plants can often survive extra cellular freezing because the cellular structures are not destroyed. As a form of frost protection, farmers sometimes spray their crops to induce this type of freezing. Slow temperature changes around 0°C often cause extra cellular freezing (Kalma et al. 1992).

The second form is intracellular freezing, which is much more injurious to crops. In this type of freezing, cells are destroyed by mechanical disruption through the formation of ice crystals in the protoplast. The end result is that the plant is killed or severely damaged. Intracellular freezing often occurs when there is a rapid decline in temperature from above the freezing point to below it (Kalma et al. 1992; Li and Saki 1982; Olien and Smith 1981; Saki and Larcher 1987).

Researchers have noted that the temperature at which a particular species freezes can vary by several degrees. Recent investigation reveals that this variation in freezing temperature is the product of an interaction between the water in plant cells and ice nucleation active (INA) bacteria (Lindow 1983a).

H_2O as a liquid does not always freeze at the melting point of its solid state. Indeed water can be supercooled well below 0°C before it freezes. For example in a controlled experiment, a small amount of pure water remained in a liquid state until it supercooled to -40°C. Under the same conditions, large volumes of pure water can be supercooled to between -10°C and -20°C before it freezes. For pure water to freeze, a significant majority of its molecules must become aligned in a lattice resembling ice. Geometric and thermodynamic factors determine the number of molecules needed within the lattice to form ice. As the temperature goes down, the number of water molecules needed to form ice declines thus promoting freezing (Lindow 1983a).

At warmer temperatures (above -10°C), the formation of ice is aided by the presence of nonaqueous or heterogeneous catalysts that assist H_2O molecules to align in the lattice needed to shift to a solid state. In nature, there are many heterogeneous ice nuclei including dust, crystals of various inorganic compounds, organic compounds such as amino acids and proteins, and bacteria. For plants, bacteria are by far the most prevalent ice nuclei available (Lindow 1983a).

In and of itself plant matter does not make very good ice nuclei. Under greenhouse conditions, many crop plants can be supercooled to temperatures of at least -8°C to -10°C without freezing their plant cells. Under field conditions, however, these same species are injured at temperatures much closer to 0°C because their supercooling is inhibited by INA bacteria (Lindow et al. 1982). Researchers have found three such bacteria that are particularly adept in inhibiting the supercooling process. These are *Pseudomonas syringae* (Van Hall), *Erwinia herbicola* (Lohnis), and *Pseudomonas fluorescens* (Migula). These bacteria cause freezing in some plant cells at -1°C and are very active in ice formation at -4°C (Lindow 1983a). Research using field samples shows that these bacteria are present in large quantities in most common plant groups except conifers (Lindow et al. 1978). The main source of these bacteria is decaying vegetative matter, and the amount of bacteria present increases with the amount of organic material available in the soil (Maki and Willoughby 1978; Lindow 1983). As the number of bacteria increases, their ability to suppress supercooling also increases (Hirano et al. 1985; Lindow et al. 1982).

Clearly if some way were found to limit the populations of these bacteria under field conditions, then the supercooling ability of crops would be greatly enhanced. Researchers are now working on a number of possibilities to achieve this end including the development of bactericides to kill the INA bacteria, of chemicals to inhibit ice nucleation by bacteria, and of antagonistic or competitive bacteria to destroy the INA bacteria (Lindow 1983b; Anderson et al. 1984). Additional research also hints at a link between moisture and bacteria populations, with an increase in the first appearing to promote an increase in the second (Ashworth et al. 1985).

GROWING SEASON LENGTH RECORD RECONSTRUCTION METHODOLOGY AND SOURCE MATERIALS

As mentioned earlier, the decision in 1948 to change the reporting parameters for growing seasons from field observations to temperature readings of 0°C has thus far made it impossible to successfully combine both types of data into a homogeneous record set. For this reason, the reconstructions that appear in this Bulletin end in 1947. As data recorded on the basis of the last occurrence of 0°C in the spring and its first occurrence in the fall is readily available from the Weather Service, we have made no attempt to reproduce the record for 1948 to the present here.

Most growing season parameter reconstructions completed to date use the 0°C approach. A few researchers have extended their records back to the period before 1948 by reconstructing daily homogeneous instrument records (Skaggs and Baker 1985). This reconstruction approach is very dependent on finding existing long-run temperature records for locations where there was little change over a long period of time in instrumentation or recording techniques. Locations also must be unaffected by the urban heat island phenomenon. Unfortunately there are few temperature data sets that meet these requirements, and the longest of these extend only into the early nineteenth century. In the few instances where such records can be located, the resulting reconstructions are directly comparable with post-1948 data and studies. Such data are scientifically derived directly from instrument records and therefore can be used for statistical studies, including the development of models to predict the length of future growing seasons, which is the primary motivation for reconstructing such records in the first place (see Table 1). Some researchers have statistically grouped records for individual locations into databases representing various climatological regions (Schmidlin and Dethier 1986).

With the exception of a study by Baron et al. (1984), no recent attempts have been made to use the earlier killing frost records based on agricultural field observations. Reconstructions presented in this Bulletin are based on this earlier data. Our motivation for developing these reconstructions differs from that of the researchers doing the work described in the preceding paragraph. Our primary goal is the study of the impact of climate variation on various New England farm operations for the period 1750 through 1900. To accomplish this task, we need to develop a series of long-run reconstructions for each climate/agricultural region within New England. Further we wish to have reconstructions available for as far back into the eighteenth century as possible. To reconstruct growing season parameters, killing frost observation data were best suited to our needs.

We grouped spring and fall killing frost observation dates by year, state, and climate zone. Only observations that clearly described a killing frost were used. All month/day style dates were converted to Julian dates. For example, May 22 is the 142nd day of the year. For leap years, we added a day to all Julian dates after

February 28. To adjust for the calendar change that took place within British colonial possessions in September of 1752, we added 11 days to all data for the period before September 1, 1752. For each year we calculated the minimum, maximum, and median dates for spring and fall killing frosts and then used this data to produce minimum, maximum, and median growing season lengths. The number of reports used to calculate each spring and fall killing frost date also were recorded.

The growing season reconstructions that appear in the following chapters were assembled from a database containing 27,800 data points representing 446 locations around New England for the time period 1663 through 1947. These data were drawn from a large number of different source materials. For the period 1700 through 1840, most observations were located in 286 diaries, farm journals, and ledgers, nearly all available only in manuscript form at some 67 archives located in the northeastern United States. A few early nineteenth century agricultural newspapers for the New England region were used to supplement this part of the database. For the period 1840 through 1892, we used three large manuscript collections available on microfilm from the National Archives. All of these records are part of Record Group 27 and include the following record sets: "Climatological Records of the Predecessors of the U.S. Weather Bureau," "Diaries and Journals Collected by the Blue Hill Observatory, Harvard University," and "Weather Bureau Miscellaneous Journals and Diaries." We supplemented these data sources with observations recorded in an additional 54 diaries available in manuscript from various archives and with data from several New England agricultural newspapers. To complete our reconstructions, we used the killing frost observations recorded in the *Annual Summary of the Climatological Service of the Weather Bureau* that appeared yearly from 1892 through 1947. A complete, detailed description of the materials used for all of our climate reconstructions will appear in a separate Bulletin.

DISCUSSION OF RESULTS

Based on linear trend analysis, a comparison of the 15 New England climate zones revealed that coastal zones experienced the greatest increases in growing season lengths averaging between 25 and 35 days longer in the 1930s and 1940s than in the late eighteenth and early nineteenth centuries. These increases were evenly divided between spring and fall. Central and intermediate zones saw smaller increases, averaging between 15 and 20 days per year, but in these locales later fall killing frosts contributed twice as much to this increase than spring frosts did. Northern and western interior zones exhibited little or no increases in the length of the growing season. For these zones in the 1930s and 1940s, killing frosts came later in the spring but also later in the fall with the net effect of canceling each other out. In Maine's Northern zone the length of the season actually decreased over all with much later spring frosts and somewhat earlier fall frosts. See Table 2.

Over the chronological length of the records, the longest growing seasons were found in the southern and coastal zones where 180-day lengths were not uncommon. Spring killing frosts in these zones occurred between April 15th and April 26th and fall frosts averaged between October 7th and October 17th. In the intermediate and western interior zones of Connecticut and Massachusetts,

Table 2. Comparison of timing of spring and fall killing frosts and growing season lengths between late eighteenth/early nineteen century seasons and those of the 1930s and 1940s.

Zone	Growing Season Range*	Spring Range*	Net**	Fall Range*	Fall Net**	Net Growing Season Increase or Decrease**
Connecticut						
Central	142–161	128–121	+7	270–282	+12	+19
Coastal	167–185	117–111	+6	284–296	+12	+18
Northwestern	136–150	134–130	+4	270–280	+10	+14
Maine						
Coastal	104–166	156–122	+34	260–288	+28	+62
Northern	133–106	131–153	-22	264–259	-5	-27
Southern Interior	122–121	133–139	-6	255–260	+5	-1
Massachusetts						
Central	137–158	129–124	+5	266–282	+16	+21
Coastal	145–190	130–108	+22	275–298	+23	+45
Northwestern	139–146	127–130	-3	266–276	+10	+7
New Hampshire						
Northern	104–120	151–145	+6	255–265	+10	+16
Southern	129–131	133–139	-6	262–270	+8	+2
Rhode Island	169–201	121–102	+19	290–303	+13	+32
Vermont						
Northeastern	116–116	141–148	-7	257–264	+7	0
Southeastern	108–118	147–147	0	255–265	+10	+10
Western	140–149	134–129	+5	274–278	+4	+9

* in Julian days
** in days

the growing seasons averaged around 140 and 150 days The seasons began around May 5th and ended during the week of October 3rd. Areas further to the north in Vermont, New Hampshire, and southern Maine had growing seasons that averaged between 130 and 140 days in length. There the last spring killing frost occurred on average between May 15th and 25th and in the fall the first killing frost occurred between September 16th and 23rd. For most northerly and westerly locations the growing seasons were the shortest with means between 110 and 120 days. Spring killing frosts occurred between May 24th and 29th with fall killing frosts during the week of September 18th. See Table 3 for further data on this subject.

Standard deviation statistics were calculated for each record. Spring killing frost date standard deviations ranged between 15 and 21 days with the largest deviations appearing in southern and coastal regions except for Maine's coastal zone. Fall killing frost date standard deviations were larger than those for the spring and ranged from 12 to 22 days. Southern and coastal regions once again had the highest standard deviations. Growing season lengths had standard deviations of between 21 and 36 days. See Table 4 for information on individual records.

THE AGRICULTURAL IMPACT OF VARIABLE GROWING SEASONS

We believe that the past is a key to understanding the possibilities of the future. In this section we wish to present a short demonstration of how our growing season reconstructions might be used in a historical setting to assess the impact of variable climate on New England agriculture.

The idea that a variable climate can have an impact on the agriculture of a region is not particularly novel, but studies detailing the degree of impact in a historical setting are relatively scarce (Smith 1989; Baron 1982a; Rotberg and Rabb 1981; Smith and Parry 1981; Wigley et al. 1981; Parry 1978). Within the past few decades, researchers have completed a number of studies on present day agricultural operations to gauge the impact of global climate change (Kaiser and Drennen 1993; Waggoner 1993; Adams et al. 1990; Cooter 1990; Parry et al. 1988; Brown 1976).

Farmers make a number of decisions every year concerning the welfare of their crops. These decisions require that the persons making them assess the risk involved in implementing or not implementing some management action. Clearly the weather often influences these decisions. For example, a variable climate that

Table 3. Mean Julian dates for spring and fall killing frosts and mean lengths of growing seasons by climate zone.

Climate Zone	Mean Fall Min.	Mean Fall Max.	Mean Fall Median	Mean Spring Min.	Mean Spring Max.	Mean Spring Median	Mean Season Min.	Mean Season Max.	Mean Season Median
Connecticut									
Central	269	285	277	116	133	125	136	169	152
Coastal	284	299	292	101	118	109	154	189	174
Northwest	270	275	272	128	136	134	132	146	137
Maine									
Coastal	265	282	272	122	140	132	127	165	143
Northern	255	268	262	134	151	143	104	134	120
Southern Interior	255	273	262	126	147	137	107	148	125
Massachusetts									
Central	261	291	273	110	139	127	122	183	148
Coastal	269	303	286	105	134	119	134	202	168
Northwestern	264	278	271	122	134	128	131	156	143
New Hampshire									
Northern	255	264	259	141	154	147	99	123	112
Southern	256	278	265	121	146	135	110	157	130
Rhode Island	282	294	293	112	126	115	156	184	180
Vermont									
Northeastern	253	267	260	137	153	144	100	131	116
Southeastern	251	265	259	143	155	149	96	121	110
Western	270	280	275	129	137	132	135	154	145
Mean	264	280	272	123	140	132	123	158	140

Table 4. Standard deviation statistics for growing season data by climate zone.

Climate Zone	Std. Dev. Fall Min.	Std. Dev. Fall Max.	Std. Dev. Fall Median	Std. Dev. Spring Min.	Std. Dev. Spring Max.	Std. Dev. Spring Median	Std. Dev. Season Min.	Std. Dev. Season Max.	Std. Dev. Season Median
Connecticut									
Central	19	22	18	23	23	20	36	40	33
Coastal	18	20	19	18	18	16	28	30	29
Northwest	15	17	15	23	15	15	24	32	25
Maine									
Coastal	22	19	19	18	20	16	38	27	28
Northern	16	15	14	15	19	16	30	22	25
Southern Interior	16	17	14	16	19	16	26	25	22
Massachusetts									
Central	21	22	19	20	21	18	34	33	29
Coastal	23	22	20	22	22	19	36	36	31
Northwestern	18	13	14	16	15	15	26	23	22
New Hampshire									
Northern	14	15	14	18	19	17	22	23	21
Southern	14	20	15	20	19	17	26	33	26
Rhode Island	15	17	16	19	17	18	26	30	28
Vermont									
Northeastern	14	13	12	16	20	16	28	21	22
Southeastern	13	14	12	16	20	16	28	21	22
Western	15	16	13	17	16	16	26	27	24
Mean	17	17	16	19	19	17	29	29	26

brings with it significant shifts in planting and harvesting dates increases the possibilities that farmers, either individually or collectively, might make incorrect decisions that could injure their crops. Under normal circumstances, farmers base their decision making on their past experiences and the recommendations of the professionals that advise them. When the physical environment begins to present situations outside the "normal" experience, however, it becomes difficult to assess which action is best at which time. If within a relatively short time span, nature presents our farmers with a number of situations that are out of the ordinary, then the entire agricultural system becomes stressed. When this environmental stress persists for some time, market constraints begin to operate to remove those farmers who fail to command sufficient economic resources to continue operation (Parry 1985; Taylor 1970; Duckham 1967; Oliver 1967; Tefertiller and Hildreth 1961).

Seen from a macro-geographic scale, farmers' decisions, taken as an aggregate, have a great impact on the amount of food available for consumption by the citizens of their region and their country and ultimately can affect the world's food supply (Rosenzweig and Parry 1993; Duckham 1974). Under extreme environmental stress, regional or national food shortages and even famines are possible (Newman 1990; Arnold 1988; Rotberg and Rabb 1983).

Environmentally imposed stress within the agricultural sector can have sweeping impacts on other sectors of the economy. Should these unpredictable environmental fluctuations continue and the number of farmers still in operation continue to decline, then out migration to other less affected regions often takes place.

Agricultural operations situated at higher elevations or at higher latitudes that are vulnerable to advective frosts are particularly sensitive to global climate changes (Parry 1975; Parry and Carter 1984) This situation occurred in northern New England during the early nineteenth century when a number of post-Revolutionary War settlers who cleared farms in upland regions during a particularly warm few decades were forced to abandon their farms when a few years later the climate reverted to its normally shorter growing season (Baron 1992b; Smith et al. 1982). Environmentally imposed stress on the agricultural sector also may have contributed to the coming of the American Revolution in southern New England as we shall see in the historical demonstration that follows.

HISTORICAL DEMONSTRATION

The settlement of New England took place during a climate episode called the Neoglacial, more commonly known as the "Little Ice Age." In Europe, the Neoglacial began somewhere around the year 1300 AD and lasted until the mid-nineteenth century. In North America, evidence for its exact advent is less precise, but sometime between 1200 and 1300 AD seems to be its probable starting point. Its ending in New England has been definitely established as between the years 1860 and 1880.

The term "Little Ice Age" brings to mind interminably long cold winters and short cool summers that encouraged the advance of glaciers. Indeed, over this 550-year period, there were many cold snowy winters, the Baltic occasionally froze over, glaciers advanced overriding Alpine villages, and the Norse colony on Greenland slowly died out cut off from Europe by year-round pack ice. Recently climatologists have found considerable evidence that has modified our view of the Neoglacial. Now we believe that this period, and especially the later third of it, was also one of contrasts. Long cold winters and short cool summers alternated with mild, nearly snowless winters and hot summers. Rains came very frequently or hardly at all. Storm frequencies increased and decreased dramatically, and growing seasons fluctuated markedly from one year to the next, by as many as 40 to 50 days.

The New England climate of our colonial forebears was no exception. In fact, climatic conditions there seem to have been more changeable than in most other locales. From the vantage point of today's relatively stable climate, we marvel at the ability of the early settlers to gain a foothold, then to make "a go of it" and finally, in some cases, to prosper. The historian, Carl Bridenbaugh, captures the essence of their secret to success in his admirable essay, "Right New-England Men; or The Adaptable Puritans" (1981), the theme of which is immediately evident from its title. While historians will recall that many New England farmers, both before and after the Revolution, did leave for more fertile regions, we are forcefully reminded by Hal S. Barron (1984) that there were "those who stayed behind" and prospered.

While New England's farmers were tested often during their first few hundred years of residence, especially in the early nineteenth century, their testing during the years just preceding the American Revolution has remained undescribed. This story involves the role of corn as New England's major food crop and the impact of a variable climate on its growth.

Compared to mean temperatures for the entire century, growing seasons for the period 1740 through 1776 in southern New England were cooler than normal with the exception of the mid-1740s and mid-1770s when summers were exceeding warm. Evidence for the early 1700s is fragmentary, but it seems to indicate that conditions were mostly cool especially during the winters. The late 1770s through the midpoint of the first decade of the nineteenth century had relatively warm growing seasons. The 1750s and 1760s are noteworthy as especially cool growing season temperatures inhibited the maturation of Indian corn (Baron 1989).

Growing season precipitation from 1740 to 1776 alternated between wet and dry on an approximately decadal basis. The 1740s were dry, the 1750s somewhat wet, the 1760s very dry, and the early 1770s somewhat dry. From 1700 to 1739, growing seasons were usually somewhat wet with the exception of the mid-1720s. The late 1770s were dry, but were followed by average to somewhat wet growing season conditions until 1807. Of special note are the dry 1740s and early 1770s and the very intense droughts of 1761, '62, '68, and '69 that hurt especially hay production but also, to some extent, corn (Baron 1992a).

During the 1740s through 1770s, a combination of uniformly clear skies (some 20% clearer than today), and frequently fluctuating cool then warm springs and falls contributed to extreme fluctuations in growing seasons with mean lengths of 150 days, a range of between 80 and 170 days, and a standard deviation of 32 days (Baron 1988, 1992a). There are insufficient data to describe the pre-1740 period except during the 1730s when there appears to be a decrease in season-to-season variability. The reconstruction for the period 1780 through 1809 is particularly interesting because it shows a marked decrease in growing season length variability (standard deviations of 17–27).

Of great importance to this study are the late May and early June killing frosts of 1740, '46, '55, '59, '63, '64, '68, '69, '75, and '76 and the early September frosts of 1745, '46, '52, '57, '60, '61, '64, '68, '70 and '71 (see Figure 1 below). During these years, corn (maize) often was killed after first sprouting in the spring and had to be replanted at great expense in time, seed, and precious specie. In the fall, the corn's growing season often was cut short, resulting in an immature crop. Fields situated in lowland areas were hurt by radiation frosts even more than those elsewhere. The great variation in spring and fall frosts inhibited the farmer in properly determining when to plant and resulted in fairly standardized planting dates within a ten-day period in mid-May. Other climate factors also had a limited impact on New England corn production. Included among these were thunder storms, heavy wind storms, and floods (Baron and Gordon 1985). What was the impact of these climatic conditions on New England corn crops during this period?

Studies attempting to quantify American agricultural production prior to 1780 have used a number of different source materials including probate records, account books and price quotations in early newspapers. To date, however, diaries and similar materials that are rich sources of agricultural information have not been used because such sources were thought to be fairly scarce. Over the last decade, the authors have conducted a systematic and thorough search of 57 archives and libraries, which revealed more than 110 diaries, many unpublished, containing considerable qualitative information on eighteenth century agricultural production. These diaries represent 76 locations around New England distributed along the coastal plain and immediately adjacent uplands from Connecticut to southern Maine and along the lower Connecticut, Merrimack, and lower Androscoggin river valleys. These materials are particularly representative of eastern Massachusetts locales.

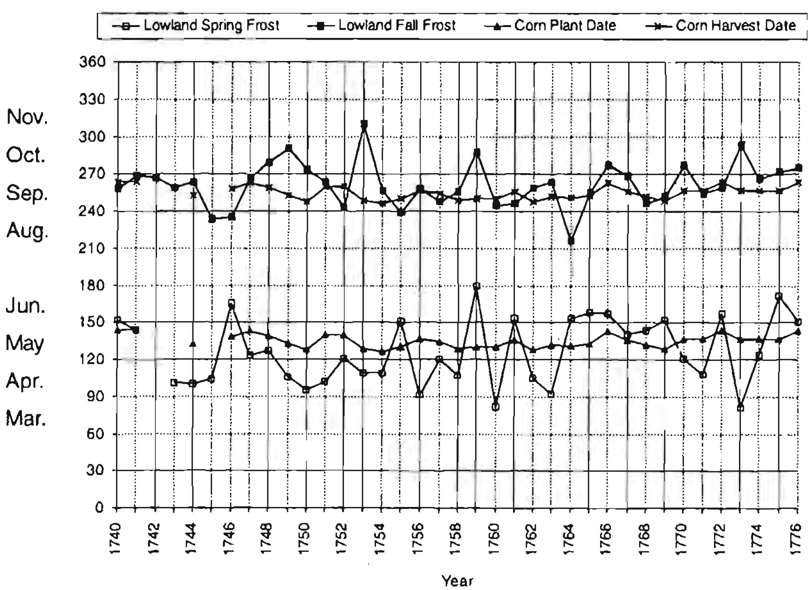

Figure 1. Eastern Massachusetts lowland area corn growing seasons, 1740–1776.

From the agricultural information collected from these manuscripts, a database of approximately 4,500 entries was built. Using content analysis methodology developed and tested previously on qualitative climate materials, the authors compiled a dictionary of agricultural production terms (Baron 1982b). Each term was defined using the *Oxford English Dictionary* to ensure correct definitions for the historical time period under study. The terms were then grouped, according to their relationship to "normal" harvests, into nine categories ranging from "very good" through "good," "much above average," "little above average," "average," little below average," "not quite poor" (much below average), "poor," to "very poor." Each category was then arbitrarily assigned a number from +4 for "very good" to -4 for "very poor". See Figure 2 for the results of these reconstructions.

Where possible, reports from several locations per year on each of New England's primary crops, including corn, hay, wheat, and apples, were analyzed using this methodology. There were numerous reports for the period 1740 through 1776 concerning corn.

Plots of crop yields for corn indicate that in 15 out of 37 years the corn crop was rated "poor" or "nearly poor" and was rated "good"

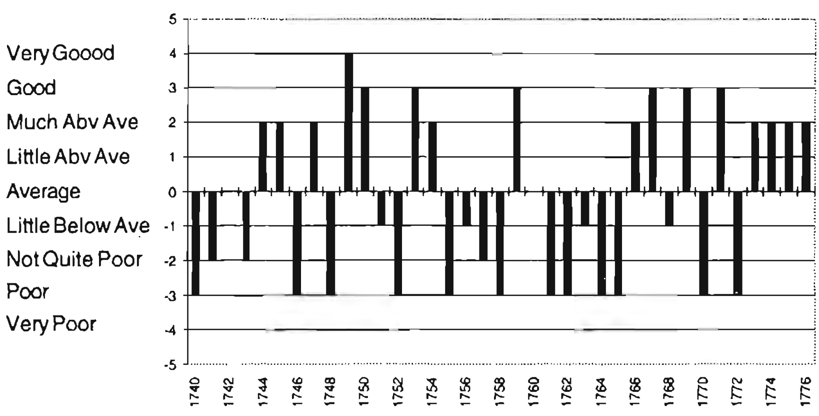

Figure 2. Eastern Massachusetts corn harvests, 1740–1776.

in only seven years. The 1760s and early 1770s were particularly hard times for corn (Baron 1989).

While such important factors as the progressive infertility of soils, insect infestations, or non-climate-related crop diseases should not be overlooked, it is clear that the fluctuating length and timing of growing seasons among other weather-related phenomena had a very adverse impact on colonial New England corn production. The decade and a half preceding the Declaration of Independence was a trying time for New England farmers. As children of the Little Ice Age, they had learned from their parents and grandparents to avoid placing "all of their eggs in one basket." As a result, we find that they grew several different crops with rather different weather requirements to ensure that at least one or two prospered in a given year. During the late colonial period, farmers grew what was needed for their families and livestock and hoped for a little extra (perhaps as much as 20%) to barter or sell for goods and services they could not provide for themselves. When frost or drought cut crop yields, farmers and their families were forced to do without.

Of the three major crops grown to produce a small surplus, corn was the most important. From 1755 through 1776 nine corn crops were rated "poor" and farmers surely lost their surpluses and probably food for family and livestock as well. As for the other two major crops of the late colonial period, hay crops were poor for eleven years and grain crops were well below average in eight seasons. In 1757, '61, '62, and '64 all three crops were a disappointment. In 1768, '71, '75, and '76, two of three crops were well below average. In all, of a possible 66 crops, 28 were rated "poor". By comparison, only 22 of the 66 crops were rated well above average. The best years for all three crops were 1759, '66, '67, '69, '73 and '74. Given what we know of New England climate and agriculture, both before and especially after the study period, it is reasonable to assume that farmers had good reason to expect better results.

Agricultural productivity in aggregate is not the only consideration of importance to historians of this period. The timing of poor crop yields was highly significant to the coming of the Revolution. Crop failures clustered in the years 1761 through 1764, just preceding the Stamp Act Crisis and in 1768 through 1772 (with the exception of 1769) during the period of unrest leading to the Coercive Acts. It does not take much imagination to perceive the mind-set of a New England farmer low on specie and/or a crop surplus for barter or his reaction to increased taxes imposed from abroad.

With agricultural surpluses low, the cost of supplies for merchants to export and more importantly for consumption by the growing urban population were rising from the 1750s on at a rate faster than the rate of increase for the New England population. For example, wheat imports from Virginia and Pennsylvania were increasing throughout the 1760s and 70s. The added pressure of agricultural shortfalls forcing up prices must surely have figured in the minds of merchants and city folk when the issue of taxes was debated.

In conclusion, after a thorough examination of these records, the authors are forced to accept the conclusion that the variable growing seasons of the mid eighteenth century deserves a place on our list of causes for the coming of the American Revolution in New England.

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Northern New England Killing Frost Regional Records

MAINE

An Introduction

The state of Maine encompasses some 33,215 square miles of mostly hilly, forested terrain. Geographically the state may be divided in half along a line running from northeast to southwest. The northwestern portion of the state is dominated by a plateau with normal elevations of between 1,000 to 1,500 feet except for the far northeast where it slopes down to 500 feet. In the western and central areas of this region there are mountains, part of the Appalachian chain, reaching elevations of between 3,000 to 5,000 feet. The southeastern half of the state, including the coast, has elevations at or below 500 feet. The central coastal region with its hilly terrain has slightly higher elevations than either the far western or eastern coastal areas. The entire state has been worked extensively during Quaternary Ice Ages by a portion of the Laurentide ice sheet which, at its greatest extent, overrode the entire state with a sheet of ice a mile thick. The glacier has helped produce a very large number of moraines, glacial out-wash areas, shallow lakes and boggy areas. The coastline is cut by numerous inlets and bays. Coastal waters are cool as they are dominated by Labrador Current and its Arctic waters as it mixes off the Maine coast with somewhat warmer local waters from the continental shelf.

Some of Maine's most important climate features that influence the length and timing of its annual growing season include (1) frequent changes in weather types and patterns, (2) a broad daily temperature range, (3) sharp differences in the character of growing seasons from one year to the next, and (4) considerable diversity in weather from one location to another. The state's weather is dominated by the flow of the Westerlies. The jet stream, the band of high-speed winds aloft that separates the subarctic cold air masses from the warm air masses of the subtropical region, frequently moves north and south over Maine as the spring and fall seasons progress. Along the boundaries of the jet are found a continuous series of storms and other meteorological systems, many of which move through or close to the state.

Three basic air mass types are common to Maine. They are cool, dry continental air usually coming from subarctic regions; warm, somewhat moist air from the Gulf of Mexico, which often is modified by its passage over the southeastern and/or central portions of the continent; and cool, damp airmasses from off of the immediate coastal waters of the North Atlantic. These air masses alternate on an often biweekly frequency in their passage over the state and result in sometimes sharp changes in temperature, moisture, wind speed and direction, and cloudiness. As a result, Maine's climate can best be described as characteristically "changeable."

On the basis of temperature data, the National Weather Service divides Maine into three climatic zones—Northern, Southern Interior, and Coastal. For our growing season reconstructions, we drew data for the period 1829 through 1947 from 13 locations in the Northern Zone, for the period 1787 through 1947 from 38 stations in the Southern Interior Zone, and for the period 1726 through 1947 from 46 observation points within the Coastal Zone. See Figure 3.

For further information please consult *Climates of the States*, volume 1 (Detroit, MI: Gale Research Company, 1978) pages 426 through 448.

Figure 3. Maine locations reporting killing frosts.

Maine Coastal Climate Zone

This zone lies in a 20- to 30-mile strip along the coast with most locations having elevations below 500 feet, with many below 100 feet. Compared to the rest of the state, locations within this zone experience temperatures that are much more influenced by the moderating effects of the ocean. The remainder of the state is more dominated by the continental land mass to the west. Growing seasons within the zone, on average, are 18 to 23 days longer than elsewhere in the state. Average spring killing frosts come earlier (May 13th) and fall frosts occur later (September 29th) than in the other climate zones. Growing seasons before 1948 were a bit shorter, 143 days on average, than those since that time, which now fall between 140 and 160 days in length. See Figures 4 and 5. The southern portions of York, Cumberland, Androscoggin, Kennebec, Waldo, Hancock, and Washington counties as well as all of Sagadahoc, Lincoln, and Knox counties fall within the Coastal Zone.

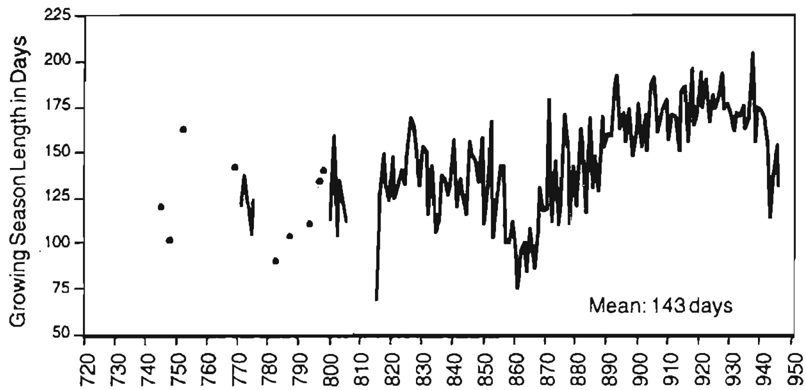

Figure 4. Coastal Maine growing season lengths, 1745–1947.

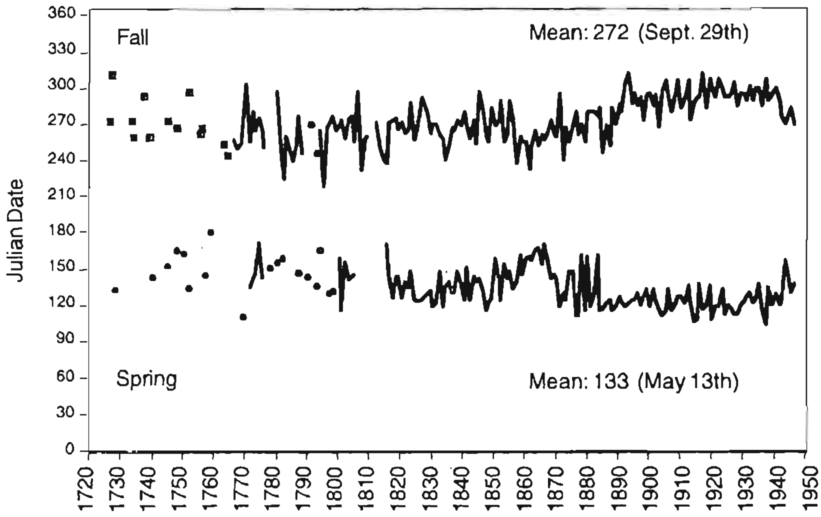

Figure 5. Coastal Maine spring and fall killing frost dates, 1726–1947.

Maine Northern Climate Zone

This zone encompasses about one half of the state's area and runs in a band from the southwest to the northeast, just north of the Southern Interior Zone. Most locations have elevations between 500 and 1,500 feet, lower locations being along the St. John River. Locations within this zone experience temperatures that are much more influenced by the continental interior while moderating maritime weather systems rarely penetrate the zone. This zone is more often influenced by cold, dry air from subarctic North America than any other zone in the state. Growing seasons within the Northern Zone, on average, are shorter (120 days) than elsewhere in the state. Average last spring killing frost comes later (May 23rd) than in the other climate zones and the fall frost occurs earlier (September 19th) than in the Coastal Zone. Growing seasons before 1948 appear to have been a bit longer, 120 days on average, than those since that time which now fall between 100 and 120 days in length. See Figures 6 and 7. The northern portions of Oxford, Franklin, Somerset, Piscataquis, and Penobscot counties as well as all of Aroostook County fall within the Northern Zone.

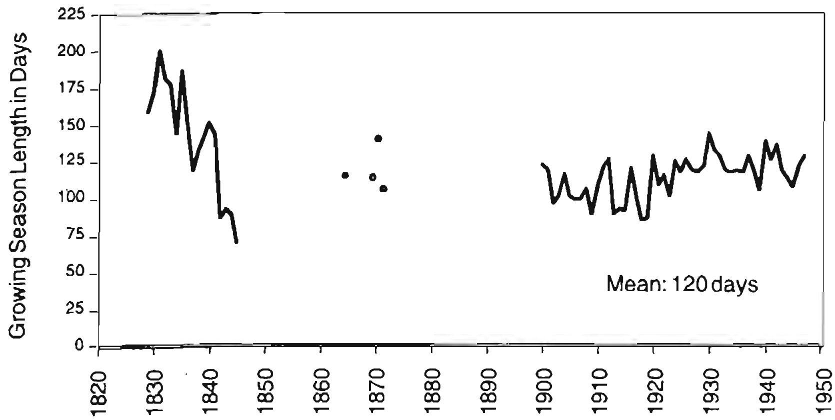

Figure 6. Northern Maine growing season lengths, 1829–1947.

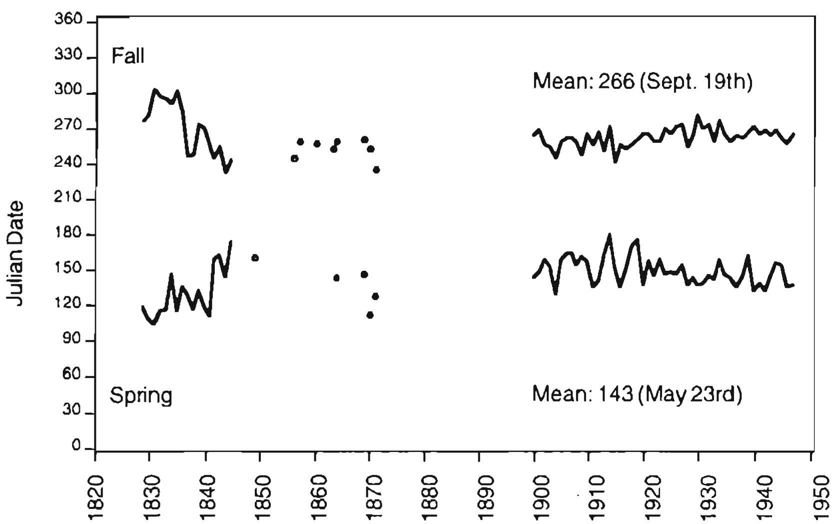

Figure 7. Northern Maine spring and fall killing frost dates, 1829–1947.

Maine Southern Interior Climate Zone

This zone covers one third of the state's area and lies between the Northern and Coastal Climate Zones. Most locations within the zone have elevations between 200 and 600 feet, with some stations having altitudes below 100 feet with locations within river valleys. This zone experiences temperatures that can sometimes be influenced by the moderating effects of cool, damp air off the ocean; more often, however, its climate is dominated by cool, dry continental air masses from the subarctic or, less frequently, by warm moist air from the Gulf of Mexico. Growing seasons within the zone are, on average, 125 days. Average spring killing frosts come six days earlier (May 17th) than those of the Northern Zone and fall frosts occur on the same day (September 29th) as the Northern Zone, but ten days earlier than those of the Coastal Zone. Growing seasons before 1948 appear to have been a bit shorter, 125 days on average, than those since that time which now fall between 120 and 140 days in length. See Figures 8 and 9. The northern portions of York, Cumberland, Androscoggin, Kennebec, Waldo, Hancock, and Washington counties as well as the southern portions of Oxford, Franklin, Somerset, Piscataquis, and Penobscot counties fall within the Southern Interior Zone.

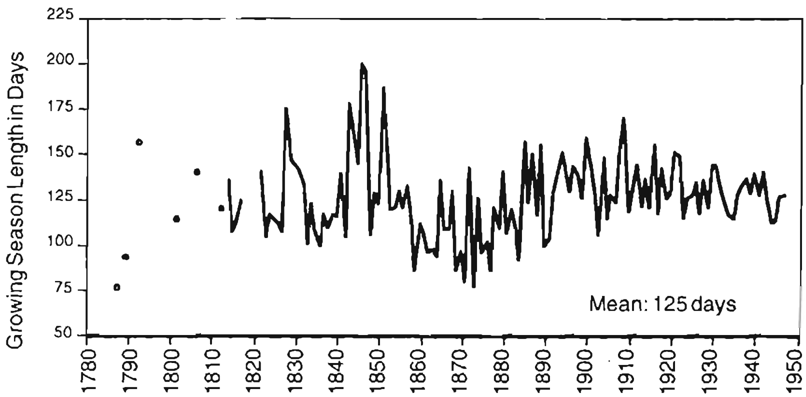

Figure 8. Southern Interior Maine growing season lengths, 1787–1947.

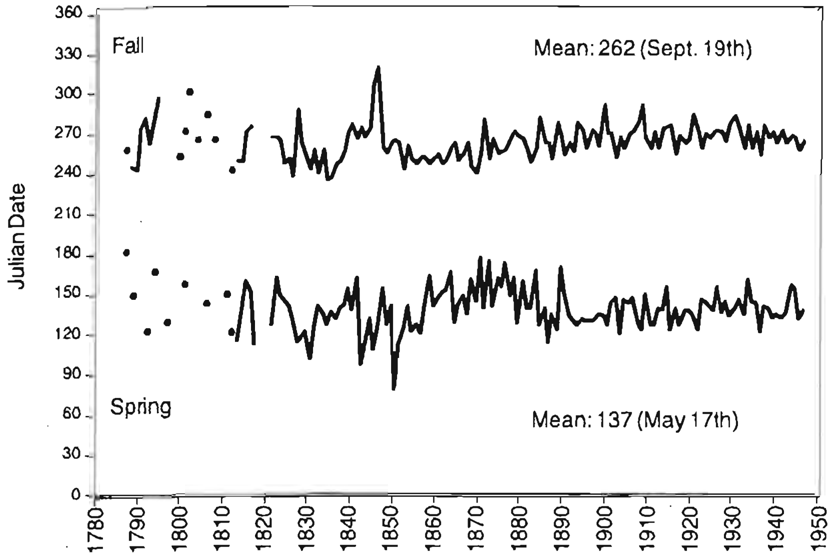

Figure 9. Southern Interior Maine spring and fall killing frost dates, 1787-1947.

NEW HAMPSHIRE AND VERMONT

An Introduction

The states of New Hampshire and Vermont are made up of some 18,913 square miles of mostly hilly to mountainous and forested terrain. Geographically the region may be divided into northern and southern climate zones with an additional zone in far western Vermont. Both states are dominated by mountain terrain having normal elevations of between 500 to 3,500 feet with some peaks reaching altitudes of 4,000 to 6,000 feet. Only in far southeastern New Hampshire along the coast and in northwestern Vermont along Lake Champlain are there elevations at or below 100 feet. The entire region has been worked extensively during Quaternary Ice Ages by a portion of the Laurentide ice sheet which at its greatest extent overrode both states with a sheet of ice more than a mile thick. The center of the region is drained by the Connecticut River.

Some of the region's most important climate features that influence the length and timing of its annual growing season include (1) frequent changes in weather types and patterns, (2) a broad daily temperature range, (3) sharp differences in the character of growing seasons from one year to the next, and (4) considerable diversity in weather from one location to another. New Hampshire and Vermont's weather is dominated by the flow of the Westerlies. The jet stream, the band of high speed winds aloft that separates the subarctic cold air masses from the warm air masses of the subtropical region, frequently moves north and south over the region as the spring and fall seasons progress. Along the boundaries of the jet are found a continuous series of storms and other meteorological systems, many of which move through or close to these states.

Three basic air mass types are common to the region. They are cool, dry continental air usually coming from subarctic regions; warm, somewhat moist air from the Gulf of Mexico, which often is modified by its passage over the southeastern and/or central portions of the continent; and cool, damp air masses from off of the immediate coastal waters of the North Atlantic. These air masses alternate on an often biweekly frequency in their passage over the region and result in sometimes sharp changes in temperature, moisture, wind speed and direction, and cloudiness. The mountainous terrain also has a profound impact on the microclimates of the region. As a result, New Hampshire and Vermont's climate can best be described as characteristically "variable."

On the basis of temperature data, the National Weather Service divides the region into three climatic zones—Northern, Southern and Western. For our growing season reconstructions, we drew data for the period 1853 through 1947 from 15 locations in New Hampshire's Northern Zone, for the period 1740 through 1947 from 44 stations in New Hampshire's Southern Zone, for the period 1816 through 1947 from 20 observation points in Vermont's Northeastern Zone, for the period 1826 through 1947 from 13 stations in Vermont's Southeastern Zone, and for the period 1816 through 1947 from 14 locations in Vermont's Western Zone.

For further information please consult *Climates of the States*, volume 2 (Detroit, MI: Gale Research Company, 1978) pages 645 through 660 and 1000 through 1013.

Figure 10. New Hampshire and Vermont locations reporting killing frosts.

New Hampshire Northern Climate Zone

This zone includes one-third of the state and encompasses west central and northern areas with elevations above 700 feet. It is least affected by air masses off of the ocean and is most dominated by its mountainous terrain, which provides for a variety of microclimates. Growing seasons within this zone on average are 18 days shorter than for the rest of the state. Before 1948, the average last spring killing frost came on May 27th, and fall killing frosts first occurred on September 16th. The average length of the growing season was 112 days. See Figures 11 and 12. Coos County and the northern portion of Grafton County fall within this zone.

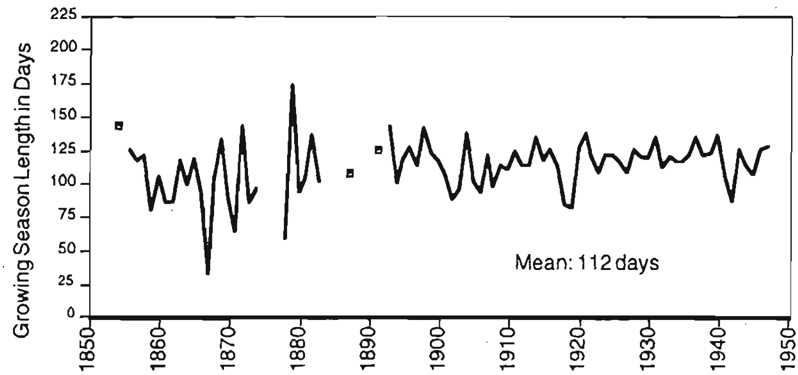

Figure 11. Northern New Hampshire growing season lengths, 1853-1947.

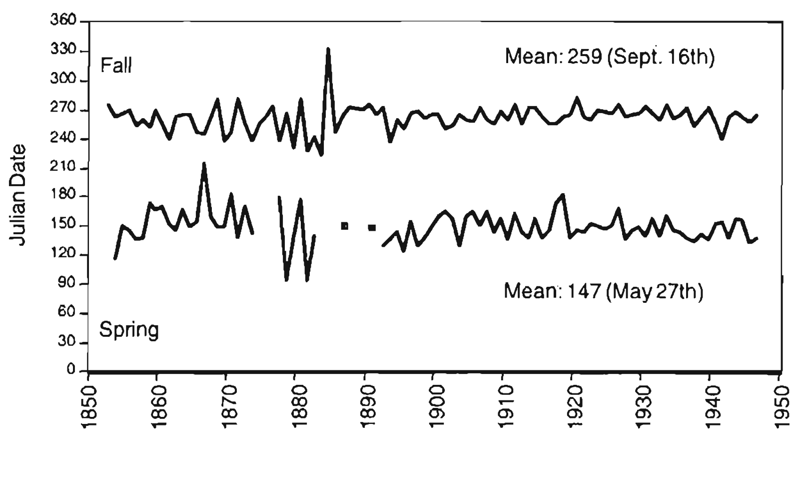

Figure 12. Northern New Hampshire spring and fall killing frost dates 1853-1947.

New Hampshire Southern Climate Zone

This zone is made up of the southern and eastern two-thirds of the state with elevations mostly below 600 feet. While the terrain is still somewhat hilly, microclimates are not as prevalent in this zone and air masses coming in off of the North Atlantic are more influential. Locations along the coast are warmest and have the longest growing seasons. The average growing season length is around 130 days in length with spring last killing frosts coming on May 15th and in the fall first around September 22nd. See Figures 13 and 14. The southern portion of Grafton County and all of Carroll, Belknap, Sullivan, Merrimack, Strafford, Cheshire, Hillsboro and Rockingham counties make up this zone.

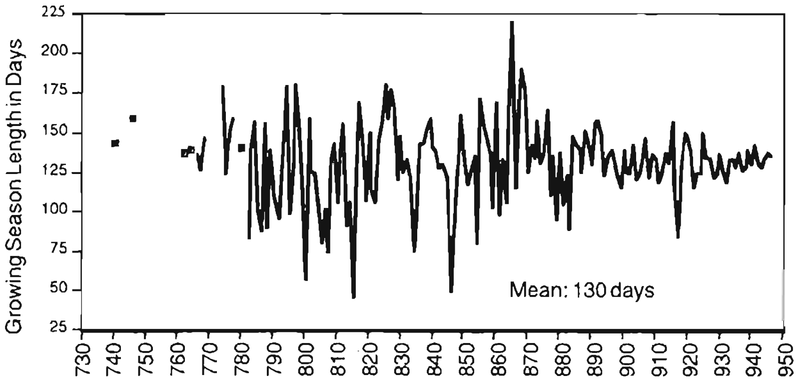

Figure 13. Southern New Hampshire growing season lengths, 1740-1947

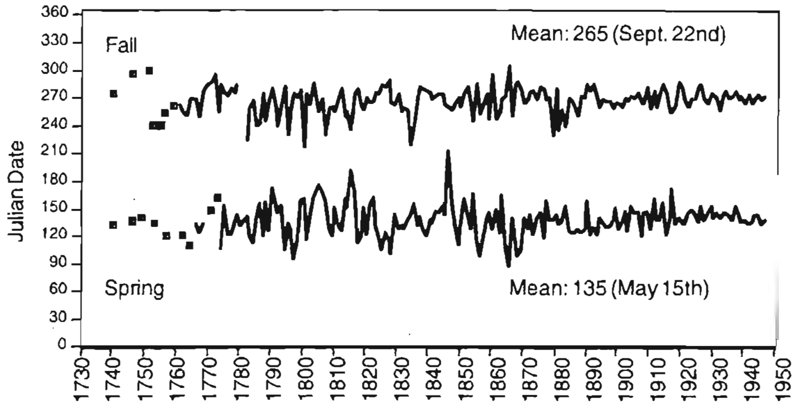

Figure 14. Southern New Hampshire spring and fall killing frost dates, 1740-1947

Vermont Northeastern Climate Zone

This zone is the largest of the three zones in Vermont and occupies the east-central and northeastern part of the state that borders on the upper Connecticut River. Much of the zone is mountainous or hilly having elevations of between 400 and 1,200 feet with a few lower elevations within the Connecticut River Valley. This region is less affected by air masses coming off of the North Atlantic and more influenced by continental and subpolar air masses. Growing seasons before 1948 averaged around 116 days with last killing frosts in the spring occurring around May 24th and first in the fall on September 17th. See Figures 15 and 16. The eastern half of Franklin and Rutland counties, the eastern tip of Addison County, and the northern part of Winsor County in addition to all of Orleans, Essex, Lamoille, Caledonia, Washington and Orange counties fall within the Northeastern Zone.

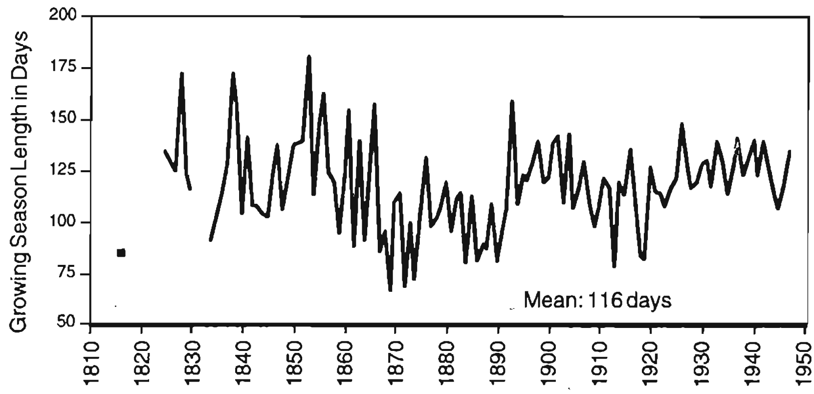

Figure 15. Northeastern Vermont growing season lengths, 1816-1947.

Figure 16. Northeastern Vermont spring and fall killing frost dates, 1816-1947.

Vermont Southeastern Climate Zone

The southeastern zone occupies the southeast section of the state that lies along the drainage of the upper Connecticut River. This area is the one in Vermont that is most easily influenced by air masses off the ocean. Most locations have elevations of between 200 and 800 feet. The terrain is mostly hilly. In spring, the last killing frost is usually around May 29th and in fall the first frost takes place around September 16th. The growing season averages 110 days which is the shortest of the three Vermont climate zones. The southeast portions of Rutland and Bennington counties and the southern half of Winsor County in addition to all of Windham County are contained in this zone.

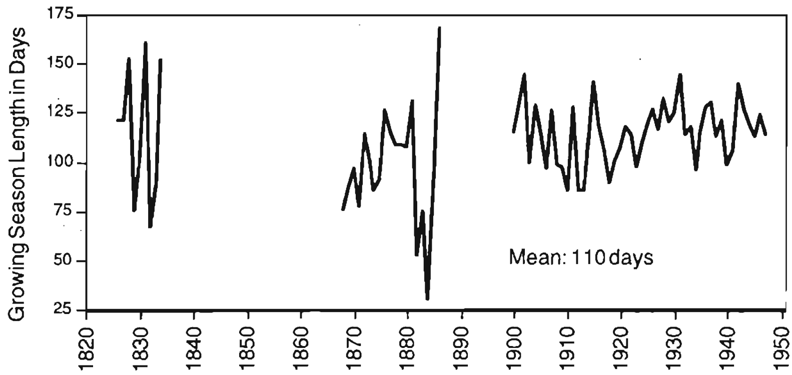

Figure 17. Southeastern Vermont growing season lengths, 1826-1947.

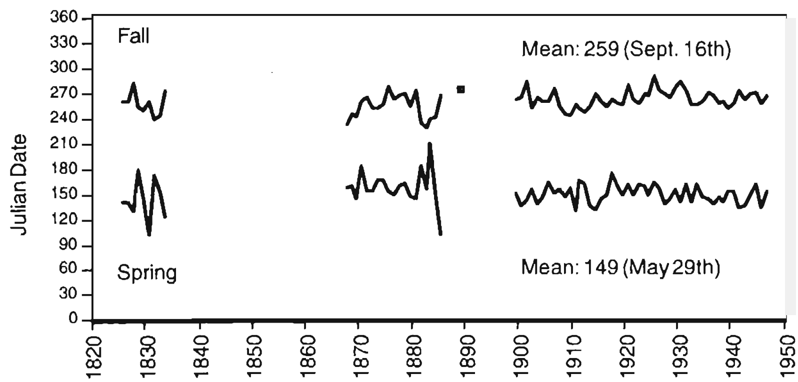

Figure 18. Southeastern Vermont spring and fall killing frost dates, 1826-1947.

Vermont Western Climate Zone

The western zone has a microclimate influenced by Lake Champlain, which lies just to the west. As a result, this is the warmest of the three climate zones within Vermont. Growing seasons are the longest, averaging 145 days with the last frost in the spring occurring around May 12th and the first fall frost coming around October 2nd. The western portions of Franklin, Addison, and Rutland counties and the central and western parts of Bennington County plus all of Grand Isle and Chittenden counties fall within the Western Climate Zone.

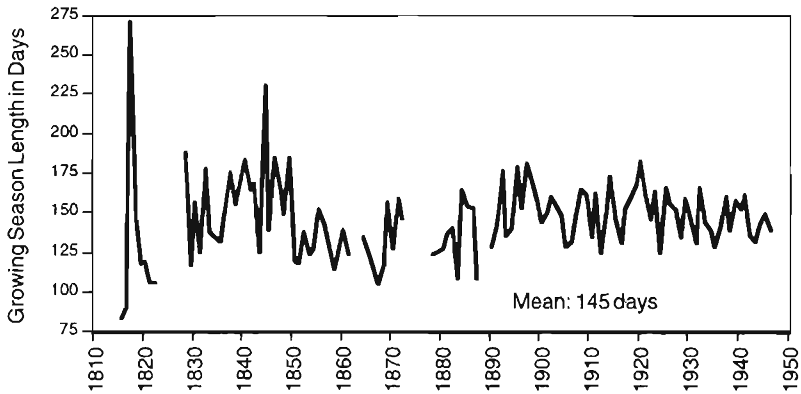

Figure 19. Western Vermont growing season lengths, 1816-1947.

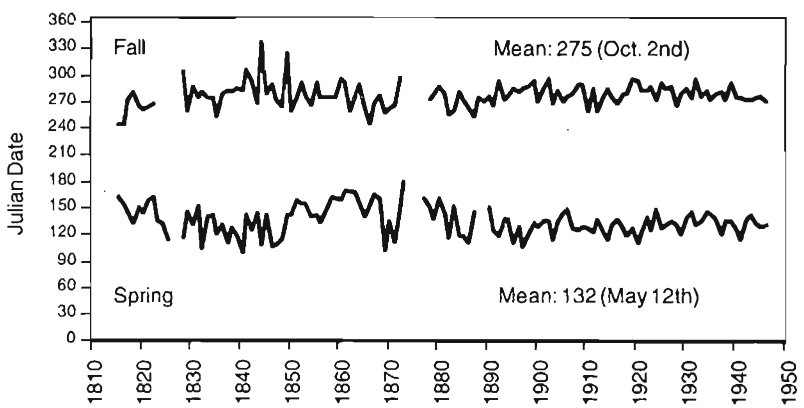

Figure 20. Western Vermont spring and fall killing frost dates, 1816-1947

Southern New England Killing Frost Regional Records

CONNECTICUT, MASSACHUSETTS, AND RHODE ISLAND

An Introduction

Southern New England contains some 14,772 square miles of mountainous to hilly to flat coastal terrain. While still partially forested with mostly deciduous trees, large parts of the area have been cleared for agricultural, industrial, and urban sites. Geographically the region may be divided into coastal, central and western regions The coastal zones of Connecticut and Rhode Island run from east to west along Long Island Sound. Rhode Island also has extensive coastline along Narragansett Bay. The coastal region of Massachusetts runs west to east along the southeastern portion of the state and then turns northward with Cape Cod reaching out into the North Atlantic. The coastal area is mostly a flat plain with numerous bays, coves, and small river mouths. Elevations range from 300 feet to below 100 feet. The central zone is made up mostly of hilly terrain with most locations having elevations of between 500 and 1,000 feet except within the larger river valleys such as those of the Connecticut and Blackstone rivers where elevations are below 500 feet in some places. The western region is mountainous with average elevations between 1,000 and 2,000 feet. This area is least developed. The entire region has been worked extensively during Quaternary Ice Ages by a portion of the Laurentide ice sheet which at its greatest extent overrode the entire area with a sheet of ice more than a mile thick. The center of the region is drained by the Connecticut River.

Some of the region's most important climate features that influence the length and timing of its annual growing season include (1) frequent changes in weather types and patterns, (2) a broad daily temperature range, (3) sharp differences in the character of growing seasons from one year to the next, and (4) considerable diversity in weather from one location to another. Southern New England's weather is dominated by the flow of the Westerlies. The jet stream, the band of high speed winds aloft that separates the subarctic cold air masses from the warm air masses of the subtropical region, frequently moves north and south over the region as the spring and fall seasons progress. Along the boundaries of the jet are found a continuous series of storms and other meteorological systems, many of which move through or close to these states.

Three basic air mass types are common to the region. They are cool, dry continental air usually coming from subarctic regions; warm, somewhat moist air from the Gulf of Mexico, which often is modified by its passage over the southeastern and/or central portions of the continent; and cool, damp air masses from off of the immediate coastal waters of the North Atlantic. These air masses alternate on an often biweekly frequency in their passage over the region and result in sometimes sharp changes in temperature, moisture, wind speed and direction, and cloudiness. The mountainous terrain of the western zone also has a profound impact on the microclimates of that area. As a result, Southern New England's climate can best be described as characteristically "changeable."

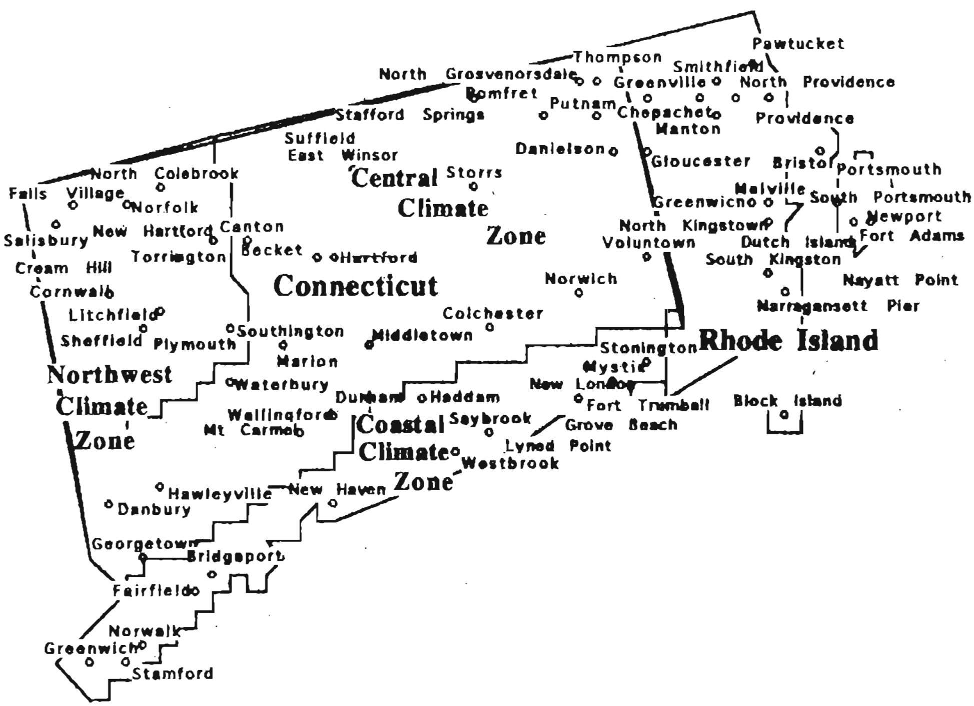

Figure 21. Connecticut and Rhode Island locations reporting killing frosts.

On the basis of temperature data, the National Weather Service divides the region into three climatic zones—Central, Coastal, and Western. For our growing season reconstructions, we drew data for the period 1785 through 1947 from 28 locations in Connecticut's Central Zone, for the period 1697 through 1947 from 16 stations within that state's Coastal Zone, for the period 1790 through 1947 from 9 observation points in Connecticut's Northwestern Zone, for the period 1723 through 1947 from 54 stations in Massachusetts' Central Zone, for the period 1704 through 1947 from 56 locations within that state's Coastal Zone, for the period 1849 through 1947 from 16 stations in Massachusetts' Western Zone and for the period 1777 through 1947 from 12 locations within Rhode Island. See Figures 3.1 and 3.2.

For further information please consult *Climates of the States* (Detroit, MI: Gale Research Company, 1978), volume 1, pages 176 through 191 and 469 through 488 and in volume 2, pages 858 through 872.

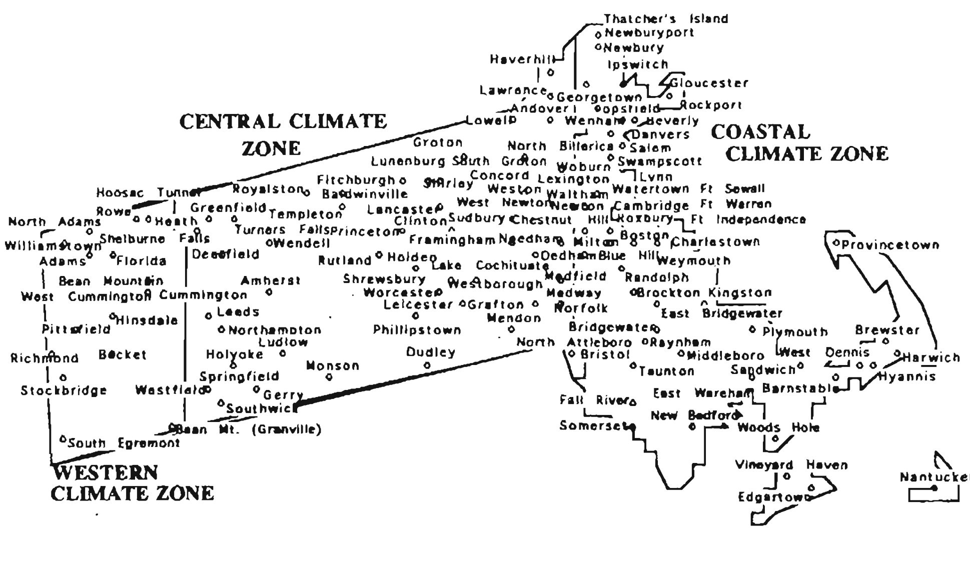

Figure 22. Massachusetts locations reporting killing frosts.

Connecticut Central Climate Zone

This zone occupies better than half of the state's area and lies north of the Coastal Climate Zone. Most locations within the zone have elevations between 200 and 400 feet, with some stations having altitudes below 100 feet with locations within river valleys. This zone experiences temperatures that can sometimes be influenced by the moderating effects of cool, damp air off the ocean; however, more often, its climate is dominated by cool, dry continental air masses from the subarctic or, less frequently, by warm moist air from the Gulf of Mexico. Growing seasons within the zone average 148 days. Average spring killing frosts come fifteen days later than those of the Coastal Zone and fall frosts occur fifteen days earlier than those of the Coastal Zone. See Figures 23 and 24. The northern portions of Fairfield, New Haven, Middlesex and New London counties as well as all of Hartford, Tolland, and Windham counties fall within this zone.

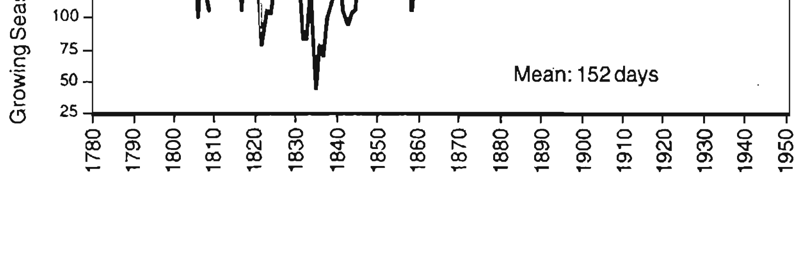

Figure 23. Central Connecticut growing season lengths, 1785–1947.

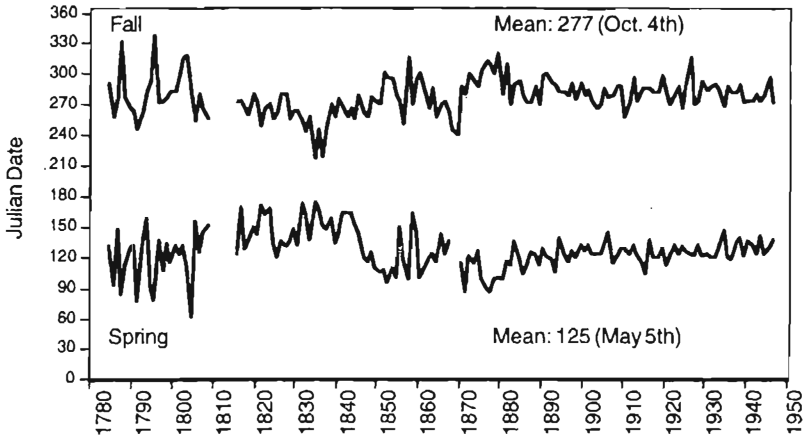

Figure 24. Central Connecticut spring and fall killing frost dates, 1785–1947.

Connecticut Coastal Climate Zone

This zone covers the area along the immediate coast. Most locations within the zone have elevations below 200 feet except for a few that are situated on hill tops. This zone experiences temperatures that are more often influenced by the moderating effects of cool, damp air off the ocean. Before 1948 average last spring killing frosts came in mid-April as they have during the past several decades, but first fall frosts were commonly observed in mid-October while recently they have occurred more toward the end of that month. Growing seasons within the zone are the longest for any climate zone within New England and average 187 days. See Figures 25 and 26. The southern portions of Fairfield, New Haven, Middlesex, and New London counties fall within the Coastal Zone.

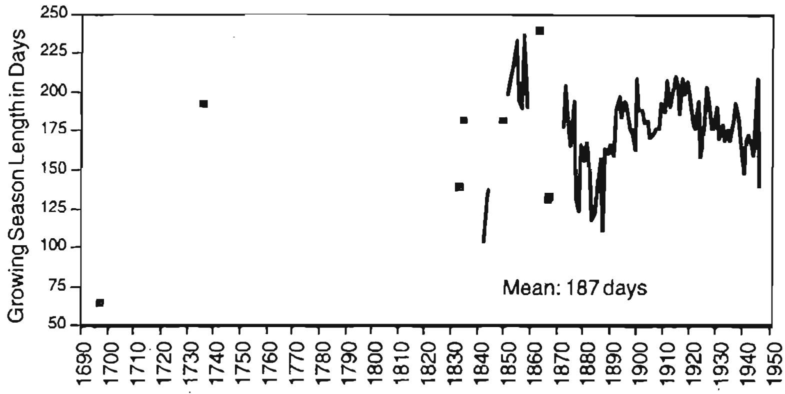

Figure 25. Coastal Connecticut spring and fall killing frost dates, 1697–1947.

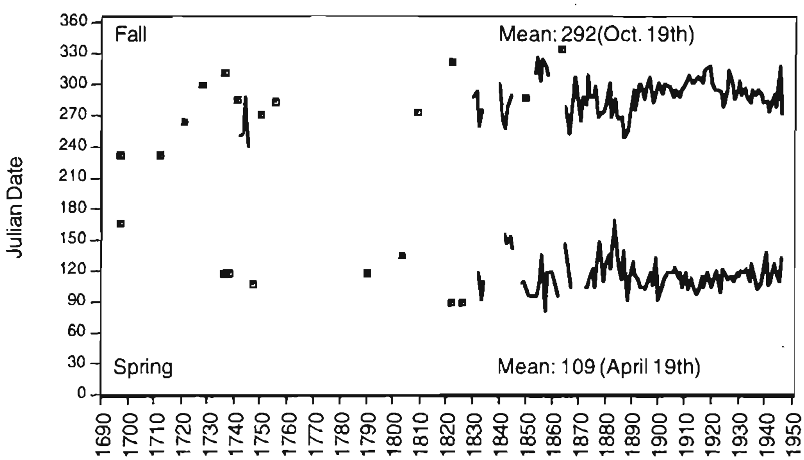

Figure 26. Coastal Connecticut growing season lengths, 1697–1947.

Connecticut Northwestern Climate Zone

This zone occupies the northwestern fifth of the state and incorporates some hilly to mountainous terrain. Most locations within this zone have elevations between 550 and 1,300 feet. This zone experiences temperatures that are less frequently influenced by the moderating effects of the ocean and its climate is more often dominated by cool, dry continental air masses from the subarctic or, less frequently, by warm moist air from the Gulf of Mexico. Growing seasons within the zone are, on average, 137 days which makes the growing season of this zone the shortest in the state. Average last spring killing frosts usually come in mid-May and first fall killing frosts occur in late September. See Figures 27 and 28. All of Litchfield County falls within this zone.

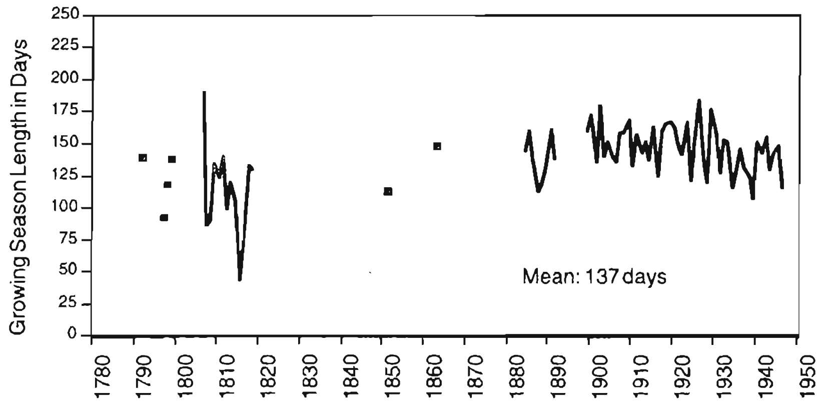

Figure 27. Northwestern Connecticut growing season lengths, 1790–1947.

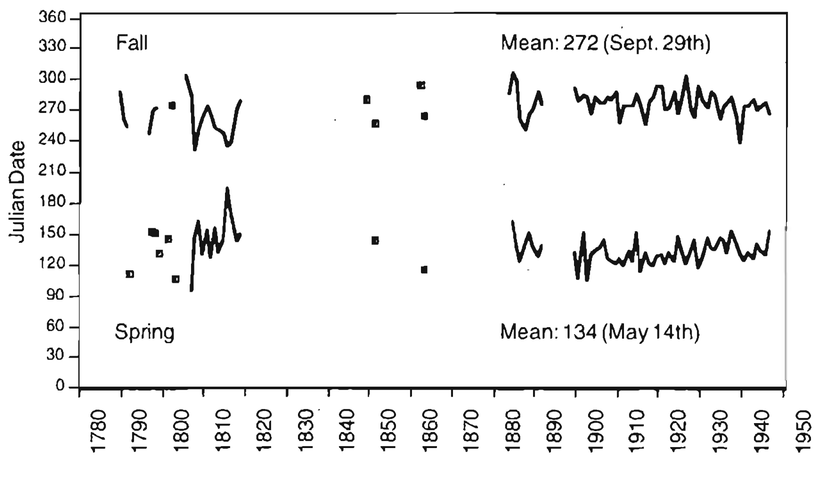

Figure 28. Northwestern Connecticut spring and fall killing frost dates, 1790–1947.

Massachusetts Central Climate Zone

This zone contains more than half of the state and lies between the Western and Coastal Climate Zones. Most locations within it have elevations between 200 and 800 feet, with some stations within river valleys having altitudes below 100 feet. This zone experiences temperatures that can sometimes be influenced by the moderating effects of cool, damp air off the ocean; however, more often, its climate is dominated by cool, dry continental air masses from the subarctic or, less frequently, by warm moist air from the Gulf of Mexico. As much of the terrain is rolling, hilly country temperature conditions can differ from location to location. Growing seasons within the zone average 148 days. Average last spring killing frosts arrive several days later (May 7th) than in the Coastal Zone and first fall killing frosts usually arrive around September 29th, which is 13 days earlier than in the Coastal Zone. See Figures 29 and 30. The eastern portions of Franklin, Hampshire, and Hampden counties, the western portions of Essex, Middlesex, and Norfolk counties, and all of Worcester County fall within the Central Zone.

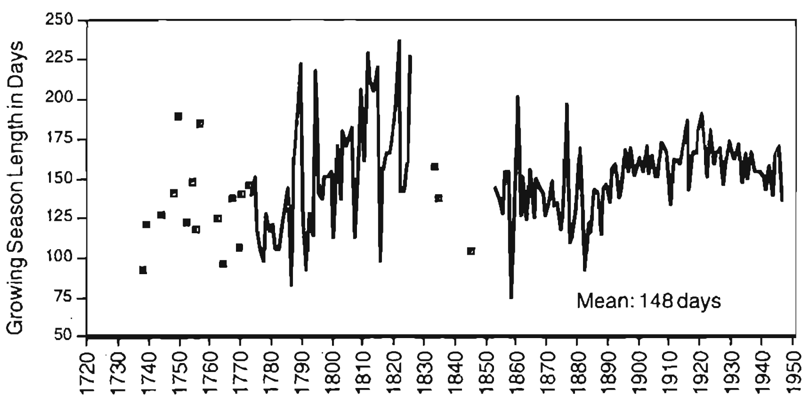

Figure 29. Central Massachusetts growing season lengths, 1723–1947.

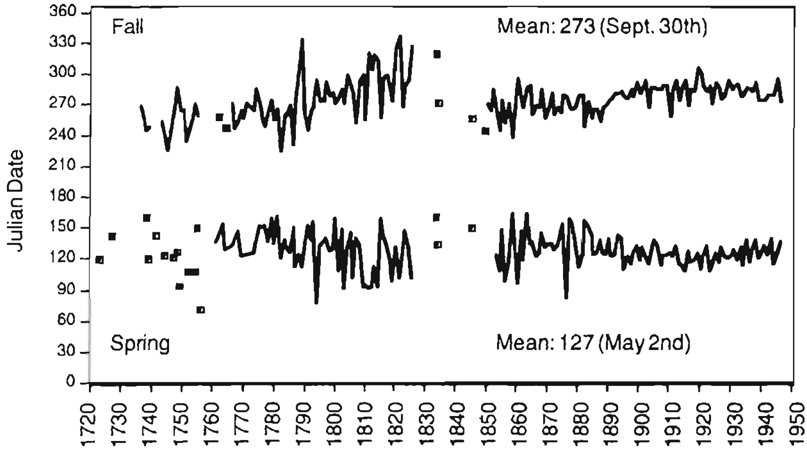

Figure 30. Central Massachusetts spring and fall killing frost dates, 1723–1947.

Massachusetts Coastal Climate Zone

This zone encompasses a 20-mile-wide band along the eastern coastline and all of the southeastern portion of the state including Cape Cod. Most locations within the zone have elevations below 200 feet. This zone experiences temperatures that are strongly influenced by the moderating effects of cool, damp air off the North Atlantic. Growing seasons within the zone were, on average, 168 days for the period before 1948, but since that time have been several days to two weeks longer. Before 1948, average last spring killing frosts occurred on April 29th and fall frosts came around October 13th. See Figures 31 and 32. The eastern portions of Essex, Middlesex, and Norfolk counties as well as all of Suffolk, Bristol, Plymouth, Barnstable, Duke, and Nantucket counties fall within this zone.

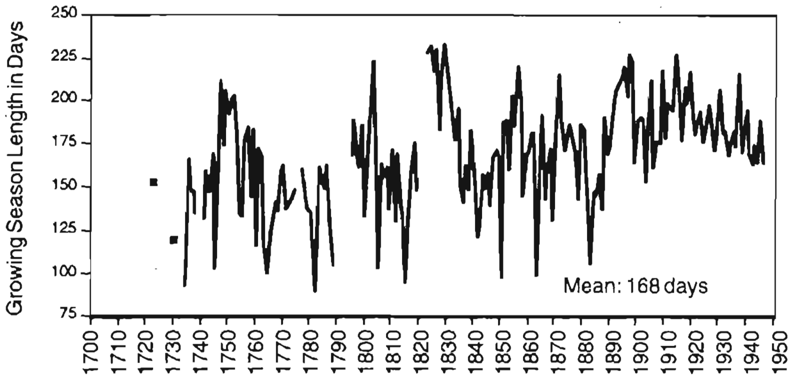

Figure 31. Coastal Massachusetts growing season lengths, 1704–1947.

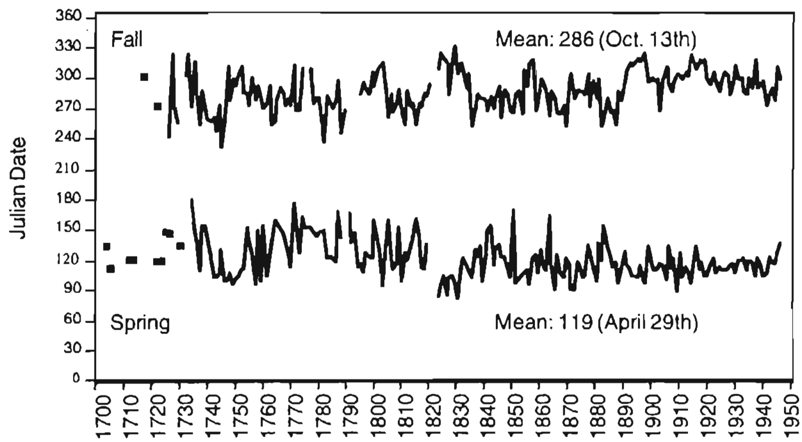

Figure 32. Coastal Massachusetts spring and fall killing frost dates, 1704–1947.

Massachusetts Western Climate Zone

This zone occupies the western quarter of the state's area and contains the Berkshire Mountains. Therefore most locations within this zone have elevations between 700 and 2,500 feet. The climate of this zone is dominated by cool, dry continental air masses from the subarctic or, less frequently, by warm moist air from the Gulf of Mexico. Growing seasons within the zone are the shortest in the state at 143 days per year. Last spring killing frosts average around May 8th, and first fall killing frosts occur on September 28th. See Figures 33 and 34. The western portions of Franklin, Hampshire and Hampden counties as well as all of Berkshire County fall within the Western Zone.

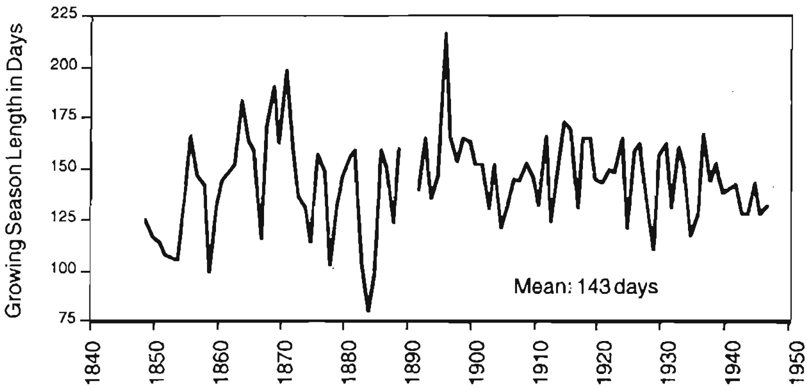

Figure 33. Western Massachusetts growing season lengths, 1849–1947.

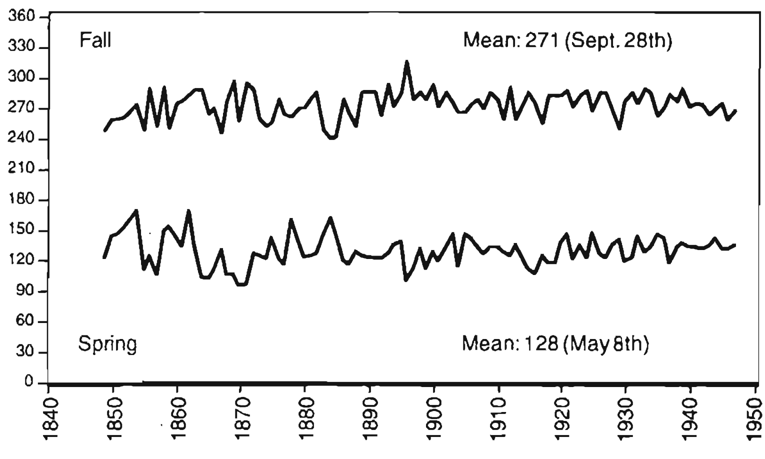

Figure 34. Western Massachusetts spring and fall killing frost dates, 1849–1947.

Rhode Island Climate Zone

Because Rhode Island's land mass is so small, the Weather Service does not divide it into climate zones. However, the area within a few miles of Narragansett and Mount Hope Bays and the southern coastal area have a microclimate that is milder than the rest of the state and features a growing season that is the longest in New England. This climatic situation is the product of the moderating influence of cool, damp air off the ocean. The remaining two-thirds of the state is composed of rolling countryside and this area is dominated more by cool, dry continental air masses from the subarctic or, less frequently, by warm moist air from the Gulf of Mexico. Growing seasons within the state as a whole average 180 days. Average last spring killing frosts come on the 25th of April and first fall killing frosts occur around October 20th. See Figures 35 and 36.

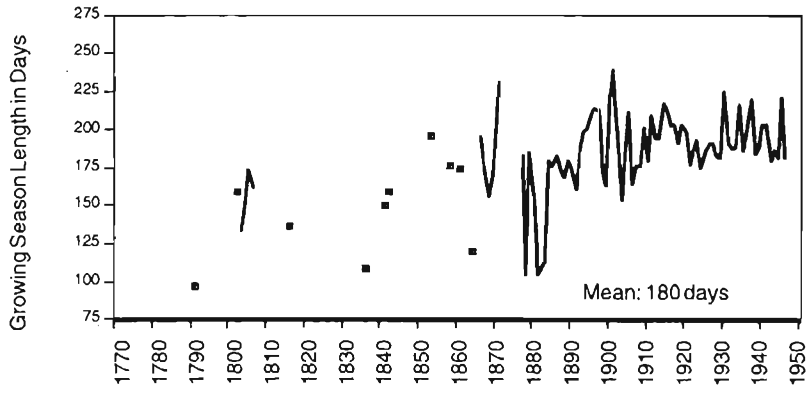

Figure 35. Rhode Island growing season lengths, 1777–1947.

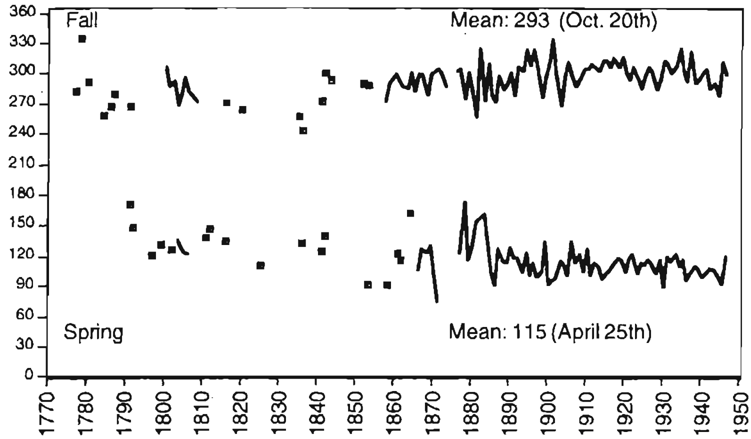

Figure 36. Rhode Island spring and fall killing frost dates, 1777–1947.

APPENDIX A

STATION RECORDS USED BY ZONES

Table A1. Central Connecticut Zone station record lengths.

	Location	Years of Frost Reports
1.	Becket	1801
2.	Canton	1891–1892, 1894–1899, 1900–1922
3.	Colchester	1887–1899, 1900–1947
4.	Conn. Literary Institute	1873
5.	Danbury	1800, 1938–1947
6.	Danielson	1904–1919
7.	Durham	1740
8.	East Windsor	1799, 1808
9.	Georgetown	1856
10.	Hamden	1785–1809
11.	Hartford	1816–1865, 1873, 1884–1947
12.	Hawleyville	1900–1916
13.	Marion	1944
14.	Middletown	1798, 1852, 1859–1875, 1900–1902, 1946–1947
15.	Mt. Carmel	1936–47
16.	N. Grosvenor Dale	1883–1886, 1891–1892, 1897–1933
17.	Norwich	1719, 1732, 1856–1857
18.	Pomfret	1781, 1853, 1855–1856, 1859–1868
19.	Prophet	1839–1840, 1857–1858
20.	Putnam	1935–1947
21.	Southington	1871–1892, 1900–1921
22.	Stafford Springs	1933
23.	Storrs	1893–1947
24.	Suffield	1777, 1779–1780, 1785, 1791
25.	Thompson	1764, 1816
26.	Voluntown	1884–1925
27.	Wallingford	1857–1861
28.	Waterbury	1887–1928, 1930–1947

Table A2. Coastal Connecticut Zone station record lengths.

Location	Years of Frost Reports
1. Bridgeport	1893–1897, 1899, 1904–1947
2. Fairfield	1809, 1816–18
3. Fort Trumbull	1831–1834, 1841–1846, 1849, 1851–1852, 1872, 1889–1891
4. Greenwich	1872–1873
5. Groton	1866–1867
6. Grove Beach	1902–1903
7. Haddam	1803
8. Lyned Point (Saybrook)	1859, 1861
9. Mystic	1877–1879, 1881
10. New Haven	1849, 1863, 1873–1947
11. New London	1712, 1721, 1728, 1736, 1738, 1741, 1743–1747, 1750, 1755, 1790, 1822, 1849, 1851–1857, 1872–1947
12. Norwalk	1891–1947
13. Saybrook	1854–1859, 1861
14. Stamford	1885
15. Stonington	1697
16. Westbrook	1940–1947

Table A3. Northwestern Connecticut Zone station record lengths.

Location	Years of Frost Reports
1. Cream Hill	1900–1947
2. Fall's Village	1931–1947
3. Litchfield	1790–1792
4. N. Colebrook	1884–1887
5. New Hartford	1888–1892
6. Norfolk	1797–1799, 1801–1803, 1806–1819, 1946–1947
7. Plymouth	1862–1863
8. Salisbury	1849, 1851, 1934–1947
9. Torrington	1902–1923

Table A4. Coastal Maine Zone station record lengths.

	Location	Years of Frost Reports
1.	Acton	1875
2.	Bakerstown	1815, 1847
3.	Bar Harbor	1886–1947
4.	Bath	1783
5.	Bedford	1759, 1768
6.	Belfast	1859–1863, 1866
7.	Berwick	1772
8.	Biddeford	1849, 1851–1852
9.	Bristol	1830–1850
10.	Brunswick	1794, 1816, 1869, 1879
11.	Bucksport	1849, 1851–1852, 1871–1873
12.	Castine	1816
13.	Dennysville	1816–1861
14.	Eastport	1873–1947
15.	Eliot	1816, 1818–1821
16.	Ellsworth	1816
17.	Falmouth (Portland)	1726, 1728, 1733–1734, 1737, 1739–1740, 1745, 1748–1759, 1763– 1786
18.	Fort Preble	1822–1824, 1841–1843, 1845, 1850, 1868, 1872, 1877, 1880–1883
19.	Fort Sullivan	1821–1832, 1841–1845, 1849, 1851
20.	Freeport	1787–1798, 1806, 1810
21.	Georgetown	1772
22.	Gorham	1773–1777, 1779–1780, 1782–1784, 1786, 1794, 1813–1818, 1822
23.	Kennebunk	1828–1850
24.	Lebanon	1767–1776, 1783–1784, 1789, 1893, 1801, 1805–1806, 1808–1809
25.	Lisbon	1859–1871
26.	Millbridge	1872
27.	Montville	1872
28.	Mount Desert	1870–1879
29.	Newcastle	1856, 1859
30.	North Yarmouth	1773–1774, 1783–1807
31.	Orland	1872
32.	Pembroke	1862
33.	Perry	1854–1858, 1863
34.	Portland	1745, 1748, 1801, 1803, 1816–1863, 1871–1947
35.	Scarborough	1727, 1816, 1832–1833, 1836, 1838, 1854
36.	Standish	1868–1877
37.	Steuben	1849–1869
38.	Thomaston	1800–1802, 1804, 1851, 1859

Table A4. Continued.

	Location	Years of Frost Reports
39.	Topsham	1859
40.	Union	1782
41.	Warren	1859
42.	Webster	1866
43.	Wells	1797–1798
44.	Windham	1854
45.	Yarmouth	1773
46.	York	1783, 1793–1794, 1800, 1816, 1836

Table A5. Northern Maine Zone station record lengths.

	Location	Years of Frost Reports
1.	Caribou	1940–1947
2.	Flagstaff	1900–1901
3.	Fort Fairfield	1842–1843
4.	Fort Kent	1841–1845, 1860, 1937–1947
5.	Greenville	1908–1947
6.	Houlton	1829–1845, 1849, 1869–1871, 1902–1947
7.	Kineo	1900–1902
8.	Millinocket	1903–1947
9.	Monson	1856–1857
10.	Presque Isle	1910–1947
11.	Ripogenus Dam	1925–1947
12.	Van Buren	1902–1935
13.	Williamsburg	1863–1864, 1869–1871

Table A6. Southern Interior Maine Zone station record lengths.

	Location	Years of Frost Reports
1.	Augusta	1816, 1832–1839, 1859, 1884, 1888
2.	Bangor	1843, 1845, 1930–1947
3.	Buckfield	1800, 1832–1867
4.	Carmel	1852–1853, 1855, 1900–1902
5.	Cornish	1856–1923
6.	Dexter	1858–1862, 1881
7.	East Corinth	1879–1880
8.	East Wilton	1861–1862, 1872–1873
9.	Exeter	1860–1861
10.	Farmington	1800, 1889–1891, 1900–1947
11.	Foxcroft	1863
12.	Fryeburg	1849, 1852–1856
13.	Gardiner	1855–1889, 1900–1947
14.	Hallowell	1787, 1789–1797, 1801–1808, 1811, 1817, 1836
15.	Hartland	1859
16.	Kennebec Arsenal	1857–1858
17.	Lee	1864–1867
18.	Lewiston	1900–1947
19.	Madison	1905–1947
20.	Mechanic Falls	1877–1878
21.	Medford	1816, 1834, 1884
22.	Minot	1838
23.	North Belgrade	1859–1860
24.	North Bridgton	1861, 1894–1947
25.	North Palermo	1872, 1874
26.	Norway	1859–1860
27.	Old Town	1925–1947
28.	Orono	1870–1945
29.	Otisfield	1848, 1851–1852
30.	Oxford	1868–1874
31.	Paris	1812–1838
32.	Piscataquis	1835
33.	Rumford	1900–1947
34.	Vanceboro	1938–1947
35.	Waterville	1885
36.	West Waterville	1863–1879
37.	Winslow	1905–1946
38.	Woodland	1924–1947

Table A7. Central Massachusetts Zone station record lengths.

	Location	Years of Frost Reports
1.	Amherst	1849–1947
2.	Andover	1764, 1768–1769, 1774, 1776, 1783, 1874–1876
3.	Baldwinville	1863–1865, 1887–1892
4.	Blue Hill	1885–1947
5.	Canton	1814–1826
6.	Clinton	1860, 1879–1880, 1905–1947
7.	Concord	1769, 1778–1780, 1782, 1787, 1789, 1792, 1890–1891, 1900–1947
8.	Deerfield	1804, 1885–1888
9.	Dudley	1883–1891
10.	Fitchburg	1861, 1885–1947
11.	Framingham	1900–1947
12.	Franklin	1874
13.	Grafton	1860
14.	Greenfield	1945–1946
15.	Groton	1859, 1900–1907
16.	Haverhill	1764, 1930–1947
17.	Holden	1932–1933
18.	Holyoke	1889
19.	Lake Cochituate	1931–1947
20.	Lancaster	1794
21.	Lawrence	1857, 1900–1947
22.	Leichester	1741, 1790, 1792, 1794, 1802, 1889–1890, 1892
23.	Lexington	1768–1769, 1771–1772, 1774, 1776, 1791–1795
24.	Lowell	1900–1947
25.	Ludlow	1890
26.	Lunenburg	1866–1867, 1869–1874
27.	Medfield	1744, 1834–1837, 1842
28.	Medway	1769–1770, 1775, 1778–1819
29.	Mendon	1849, 1854–1879, 1883
30.	Monson	1900–1911
31.	Needham	1768, 1772, 1775, 1801
32.	North Attleboro	1851–1855
33.	North Billerica	1866–1881, 1889–1892
34.	Northampton	1845, 1874, 1909–1910
35.	Phillipston	1816–1817, 1819
36.	Princeton	1860–1870
37.	Royalston	1783, 1805, 1888–1892
38.	Rutland	1763–1765, 1902–1923
39.	Shelburne Falls	1931–1947
40.	Shirley	1770

Table A7. Continued.

	Location	Years of Frost Reports
41.	Shrewsbury	1752, 1756, 1762, 1764, 1767, 1770, 1772, 1777–1808
42.	South Groton	1859
43.	Southwick	1849, 1851, 1854–1855
44.	Springfield	1855–1856, 1859, 1864–1865, 1875–1882, 1900–1901, 1924–1947
45.	Sudbury	1769
46.	Templeton	1795–1805
47.	Turners Falls	1904–1947
48.	Waltham	1769–1771, 1774, 1787, 1798–1799, 1871–1879
49.	Wendell	1874–1876
50.	Westboro	1737–1755, 1875–1891
51.	Westfield	1855–1866, 1931–1947
52.	Weston	1723, 1891, 1931–1947
53.	Woburn	1783, 1786, 1808–1811, 1813
54.	Worcester	1727, 1738, 1797–1798, 1809, 1816–1818, 1854–1947

Table A8. Coastal Massachusetts Zone station record lengths.

	Location	Years of Frost Reports
1.	Barnstable	1852–1853
2.	Beverly	1817
3.	Boston	1727–1782, 1872–1947
4.	Brewster	1890
5.	Bristol	1902
6.	Brockton	1931–1947
7.	Cambridge	1743–1765, 1777, 1856–1859, 1868–1872, 1877–1892
8.	Charleston	1692, 1882–1883
9.	Chestnut Hill	1900–1947
10.	Danvers	1746, 1755, 1794, 1801, 1805
11.	Dedham	1745, 1756–1767, 1774–1776, 1781–1783
12.	East Bridgewater	1806–1820, 1828–1830, 1832–1833, 1846–1847
13.	East Wareham	1930–1947
14.	Edgartown	1946–1947
15.	Fall River	1861, 1874–1892, 1900–1947
16.	Ft. Independence	1824–1836, 1852–1860, 1866–1879
17.	Ft. Sewell	1820, 1836–1844, 1878
18.	Ft. Warren	1863–1883, 1889–1891

Table A8. Continued.

	Location	Years of Frost Reports
19.	Georgetown	1865–1868, 1871
20.	Gerry	1799–1801, 1805
21.	Gloucester	1812, 1930–1946
22.	Hingham	1756–1757, 1760–1761, 1763–1764
23.	Hyannis	1900–1911, 1930–1947
24.	Ipswich	1782
25.	Kingston	1787, 1866–1873, 1902
26.	Lynn	1741, 1746
27.	Middleboro	1900–1915
28.	Milton	1868–1892
29.	Nantucket	1852, 1854–1859, 1887–1947
30.	New Bedford	1800, 1854–1892, 1900–1947
31.	Newbury	1737–1738, 1747, 1772, 1843, 1852, 1854–1855, 1864–1874, 1880, 1887–1890
32.	Newburyport	1843, 1852, 1873–1874, 1880, 1887–1890
33.	Newton	1931–1932
34.	Norfolk	1903–1915
35.	Plymouth	1801, 1905–1947
36.	Provincetown	1802, 1882–1883, 1888–1889, 1891–1892, 1900–1943
37.	Randolph	1862
38.	Raynham	1755, 1761–1762
39.	Rockport	1902–1939, 1947
40.	Roxbury	1664, 1668, 1740
41.	Salem	1712–1713, 1744–1746, 1750, 1752, 1755, 1762, 1775–1776, 1778, 1780, 1784–1790, 1792, 1816, 1839
42.	Sandwich	1863–1865, 1946–1947
43.	Somerset	1872–1892
44.	Swampscot	1931–1947
45.	Taunton	1883–1892, 1929–1947
46.	Thatcher's Island	1877, 1879–1883
47.	Topsfield	1860–1870
48.	Vineyard Haven	1875
49.	Watertown	1843
50.	Watertown Arsenal	1843–1844
51.	Wenham	1717
52.	West Bridgewater	1817
53.	West Dennis	1864
54.	West Newton	1867, 1869, 1870
55.	Weymouth	1763–1772, 1778, 1783–1784, 1787, 1793
56.	Woods Hole	1852, 1877–1880, 1887–1892

Table A9. Western Massachusetts Zone station record lengths.

	Location	Years of Frost Reports
1.	Adams	1931–1947
2.	Beane Mountain	1880–1882
3.	Becket	1801
4.	Cummington	1903–1906
5.	Florida	1857–1860, 1872–1876, 1891
6.	Heath	1882–1889, 1892
7.	Hinsdale	1868–1871, 1875–1876
8.	Hoosac Tunnel	1931–1947
9.	Mount Tom	1901–1907
10.	North Adams	1871–1872, 1874
11.	Pittsfield	1851–1852, 1900–1901, 1926–1947
12.	Richmond	1849–1852, 1854–1863, 1865–1872
13.	Rowe	1877–1885
14.	South Egremont	1902–1907, 1909–1911
15.	Stockbridge	1807, 1930–1947
16.	Williamstown	1797–1798, 1855–1861, 1864–1871, 1874–1943

Table A10. Northern New Hampshire Zone station record lengths.

	Location	Years of Frost Reports
1.	Benton	1910–1914
2.	Berlin	1924–1947
3.	Berlin Mills	1886–1887, 1890, 1900–1905
4.	Bethlehem	1893–1947
5.	Errol	1930–1940
6.	First Connecticut Lake	1935–1947
7.	Grafton	1879–1883, 1900–1947
8.	Groveton	1891–1892
9.	Littleton	1863
10.	Mount Washington	1877–1878, 1884–1885, 1888
11.	Pinkham Notch	1930–1947
12.	Pittsburg	1919–1934
13.	Shelburne	1855–1876
14.	Stratford	1853–1873, 1900–1905
15.	Whitefield	1869–1875

Table A11. Southern New Hampshire Zone station record lengths.

	Location	Years of Frost Reports
1.	Alstead	1900–1922
2.	Amoskeag	1875
3.	Antrim	1867–1871, 1878–1891
4.	Auburn	1874–1882
5.	Bedford	1755–1756, 1763–1765, 1767–1768, 1770, 1774–1775, 1777–1778, 1781, 1783, 1786
6.	Boscawen	1825–1834
7.	Bristol	1883
8.	Canterbury	1891
9.	Chichester	1819–1825
10.	Claremont	1857–1867
11.	Concord	1746, 1764, 1780, 1794, 1816–1817, 1849–1857, 1865–1866, 1871–1947
12.	Contooksville	1871–1885
13.	Dover	1767–1778, 1784, 1786, 1812–1815
14.	Dublin	1849–1852
15.	Dunbarton	1868–1879
16.	Durham	1900–1947
17.	Epping	1796–1797, 1802–1804, 1808–1823
18.	Exeter	1740, 1749, 1751, 1753, 1759, 1762, 1764–1765, 1768, 1772, 1776–1777, 1780, 1854–1855, 1861–1862
19.	Farmington	1879
20.	Francestown	1857
21.	Franklin	1907–1947
22.	Ft. Constitution	1823–1845, 1848–1852
23.	Hampton Falls	1776–1780, 1785–1786, 1788, 1791–1792, 1794–1795, 1800, 1803, 1806, 1808–1810
24.	Hanover	1804, 1807, 1828, 1835–1845, 1853–1854, 1885–1947
25.	Hawke	1783, 1788, 1791–1792, 1794, 1801, 1806, 1808, 1812
26.	Keene	1893–1947
27.	Londonderry	1849–1855
28.	London Ridge	1862
29.	Manchester	1852, 1854–1857, 1887–1892, 1932–1947
30.	Marlborough	1820–1851
31.	Mill Village	1875, 1889
32.	Nashua	1885–1889, 1900–1917, 1930–1947
33.	New Found Lake	1884
34.	Newmarket	1882
35.	Plymouth	1900–1947
36.	Portsmouth	1757, 1762, 1769, 1777, 1784, 1839–1842
37.	Sanbornton	1783–1829

Table A11.Continued.

	Location	Years of Frost Reports
38.	Somerworth	1854–1855
39.	South Antrim	1867
40.	Stratham	1752, 1783, 1789, 1794, 1859
41.	Tamworth	1870–1873
42.	Wakefield	1817–1819
43.	Weare	1794, 1817
44.	Weirs	1794, 1804, 1817

Table A12.Rhode Island Zone station record lengths.

	Location	Years of Frost Reports
1.	Block Island	1883–84, 1887–1888, 1897, 1900–1947
2.	Bristol	1787, 1802, 1900–1924
3.	Chepachet	1878
4.	Dutch Island	1874
5.	Fort Adams	1842–1843, 1852–1853, 1859, 1867, 1870, 1880
6.	Kingston	1780, 1784, 1786, 1799, 1804, 1809, 1811–1812, 1816, 1820, 1825, 1889–1890, 1900–1947
7.	Manton	1799, 1801, 1804–1807
8.	Narragansett Pier	1900–1918
9.	Newport	1777–1778, 1835–1836, 1841, 1865–1870, 1872–1874, 1877–1882
10.	Nyatt Point	1884–1885
11.	Providence	1791–1792, 1797, 1799, 1801, 1803–1806, 1858–1859, 1861–1864, 1866–1867, 1879, 1884–1947
12.	Smithfield	1802–1803, 1807, 1853

Table A13. Northeastern Vermont Zone station record lengths

	Location	Years of Frost Reports
1.	Barnet	1817
2.	Berkshire	1888–1891
3.	Bloomfield	1906–1947
4.	Brookfield	1863
5.	Chelsea	1900–1947
6.	Coventry	1889
7.	Craftsbury	1854–1874, 1935–1946
8.	East Barnet	1931–1947
9.	Enosburg	1891–1942
10.	Garfield	1924–1932
11.	Lunenburgh	1859–1891
12.	Newbury	1816–1817
13.	Newport	1870–1886, 1930–1947
14.	Northfield	1887–1947
15.	Randolph	1829–1873, 1883, 1886
16.	Ryegate	1824–1828
17.	St Johnsbury	1854–1859, 1888–1889, 1900–1947
18.	Strafford	1873–1892
19.	Stowe	1885–1886
20.	Troy	1872

Table A14. Southeastern Vermont Zone station record lengths.

	Location	Years of Frost Reports
1.	Brattleboro	1849, 1885–1886, 1931–1941
2.	Cavendish	1903–1910, 1924–1947
3.	Fayettville (Newfane)	1826–1834
4.	Hartford	1869
5.	Hartland	1889, 1900–1903
6.	Jacksonville	1900–1911
7.	Norwich	1871–1876
8.	Post Mills	1886
9.	Vernon	1900–1902, 1925–1933
10.	Westminster	1876
11.	White River Junction	1942–1947
12.	Windsor	1880–1881
13.	Woodstock	1868–1885, 1900–1947

Table A15. Western Vermont Zone station record lengths.

	Location	Years of Frost Reports
1.	Bennington	1871, 1900–1901, 1924, 1930–1945
2.	Brandon	1855–1866
3.	Burlington	1832–1856, 1881–1947
4.	Castleton	1852–1855, 1869–1874
5.	Charlotte	1868–1873, 1878–1887
6.	Cornwall	1900–1906, 1910–1947
7.	Ferrisburgh	1869–1871
8.	Manchester	1888–1889, 1900–1947
9.	Middlebury	1849, 1851, 1865–1969, 1888
10.	Rupert	1859
11.	Rutland	1863, 1924–1947
12.	St Albans	1930–1947
13.	Wallingford	1816–1836, 1857
14.	Wells	1892–1920

Appendix B

GEOGRAPHIC DATA ON STATION RECORDS BY ZONE

Table B1. Central Connecticut Zone station geographic information.

Location	Latitude	Longitude	Elevation	County
1. Becket	42° 20'	73° 05'	200'	New Haven
2. Canton	41° 50'	72° 50'	650'	Hartford
3. Colchester	41° 35'	72° 20'	435'	New London
4. Conn. Literary Institute	42° 00'	72° 37'	124'	Hartford
5. Danbury	41° 24'	73° 28'	510'	Fairfield
6. Danielson	41° 48	71° 53	160'	Windham
7. Durham	41° 29'	72° 41'	320'	Middlesex
8. East Windsor	41° 50'	72° 38'	86'	Hartford
9. Georgetown	41° 24'	73° 25'	300'	Fairfield
10. Hamden	41° 21'	72° 56'	200'	New Haven
11. Hartford	41° 46'	72° 42'	63'	Hartford
12. Hawleyville	41° 26'	73° 21'	280'	Fairfield
13. Marion	41° 34'	72° 56'	310'	Hartford
14. Middletown	41° 33'	72° 45'	370'	Middlesex
15. Mount Carmel	41° 24'	72° 54'	180'	New Haven
16. N. Grosvenor Dale	41° 59'	71° 54'	250'	Windham
17. Norwich	41° 30'	72° 09'	300'	New London
18. Pomfret	72° 13'	41° 52'	200'	Windham
19. Prophet	?	?	?	Hartford
20. Putnam	41° 55'	71° 55'	200'	Windham
21. Southington	41° 35'	72° 51'	140'	Hartford
22. Stafford Springs	41° 47'	72° 18'	455'	Tolland
23. Storrs	41° 48'	72° 15'	650'	Tolland
24. Suffield	42° 00'	72° 37'	124'	Hartford
25. Thompson	41° 57'	71° 51'	600'	Windham
26. Voluntown	41° 35'	71° 50'	260'	New London
27. Wallingford	41° 28'	72° 51'	390'	New Haven
28. Waterbury	41° 35'	73° 02'	333'	New Haven

Table B2. Coastal Connecticut Zone station geographic information.

Location	Latitude	Longitude	Elevation	County
1. Bridgeport	41° 12'	73° 12'	144'	Fairfield
2. Fairfield	41° 08'	73° 16'	253'	Fairfield
3. Fort Trumbull	41° 21'	72° 08'	23'	New London
4. Greenwich	41° 06'	73° 42'	450'	Fairfield
5. Groton	41° 12'	72° 21'	25'	New London
6. Grove Beach	41° 16'	72° 29'	20'	Middlesex
7. Haddam	41° 29'	72° 31'	100'	Middlesex
8. Lyned Point (Saybrook)	41° 16'	72° 20'	10'	Middlesex
9. Mystic	41° 26'	72° 18'	6'	New London
10. New Haven	41° 18'	72° 56'	30'	New Haven
11. New London	41° 21'	72° 06'	60'	New London
12. Norwalk	41° 05'	73° 02'	650'	Fairfield
13. Saybrook	41° 16'	72° 20'	10'	Middlesex
14. Stamford	41° 07'	73° 31'	400'	Fairfield
15. Stonington	41° 20'	71° 54'	50'	New London
16. Westbrook	41° 18'	72° 26'	40'	Middlesex

Table B3. Northwestern Connecticut Zone station geographic information.

Location	Latitude	Longitude	Elevation	County
1. Cream Hill	41° 52'	73° 20'	1300'	Litchfield
2. Fall's Village	41° 57'	73° 22'	580'	Litchfield
3. Litchfield	41° 44'	73° 11'	600'	Litchfield
4. New Hartford	42° 02'	73° 04'	800'	Litchfield
5. Norfolk	42° 00'	73° 10'	1300'	Litchfield
6. North Colebrook	42° 06'	73° 06'	900'	Litchfield
7. Plymouth	41° 40'	73° 03'	550'	Litchfield
8. Salisbury	42° 00'	73° 18'	737'	Litchfield
9. Torrington	41° 48'	73° 07'	580'	Litchfield

Table B4. Coastal Maine Zone station geographic information.

Location	Latitude	Longitude	Elevation	County
1. Acton	43° 30'	70° 50'	750'	York
2. Bakerstown	43° 28'	70° 52'	350'	York
3. Bar Harbor	44° 23'	68° 12'	30'	Hancock
4. Bath	43° 54'	69° 49'	60'	Sagadahoc
5. Bedford	?	?	55'	York
6. Belfast	44° 24'	69° 00'	20'	Waldo
7. Berwick	43° 15'	70° 52'	60'	York
8. Biddeford	43° 31'	70° 26'	45'	York
9. Bristol	43° 48'	69° 30'	150'	Lincoln
10. Brunswick	43° 53'	69° 56'	70'	Cumberland

Table B4. Continued.

Location	Latitude	Longitude	Elevation	County
11. Bucksport	44° 30'	68° 42'	90'	Hancock
12. Castine	44° 22'	68° 50'	85'	Hancock
13. Dennysville	44° 50'	67° 15'	42'	Washington
14. Eastport	44° 59'	66° 59'	33'	Washington
15. Eliot	43° 07'	70° 50'	40'	York
16. Ellsworth	44° 32'	68° 25'	24'	Hancock
17. Falmouth (Portland)	43° 39'	70° 20'	50'	Cumberland
18. Fort Preble	43° 39'	70° 20'	50'	Cumberland
19. Fort Sullivan	44° 54'	66° 56'	30'	Washington
20. Freeport	43° 48'	70° 09'	42'	Cumberland
21. Georgetown	43° 47'	69° 57'	60'	Lincoln
22. Gorham	43° 34'	70° 30'	165'	Cumberland
23. Kennebunk	43° 23'	70° 32'	48'	York
24. Lebanon	43° 20'	70° 55'	187'	York
25. Lisbon	44° 00'	70° 04'	130'	Androscoggin
26. Millbridge	44° 20'	67° 49'	51'	Washington
27. Montville	44° 23'	69° 20'	575'	Waldo
28. Mount Desert	44° 18'	68° 17'	75'	Hancock
29. Newcastle	44° 07'	69° 35'	88'	Lincoln
30. North Yarmouth	43° 50'	70° 18'	178'	Cumberland
31. Orland	44° 34'	68° 45'	180'	Hancock
32. Pembroke	44° 53'	67° 15'	25'	Washington
33. Perry	44° 58'	67° 04'	100'	Washington
34. Portland	43° 39'	70° 20'	50'	Cumberland
35. Scarborough	43° 31'	70° 21'	46'	Cumberland
36. Standish	43° 45'	70° 30'	280'	Cumberland
37. Steuben	44° 44'	67° 55'	50'	Washington
38. Thomaston	44° 04'	69° 11'	110'	Knox
39. Topsham	43° 57'	69° 58'	100'	Sagadahoc
40. Union	44° 12'	69° 16'	156'	Knox
41. Warren	44° 45'	69° 13'	105'	Lincoln
42. Webster	44° 04'	70° 04'	75'	Androscoggin
43. Wells	43° 18'	70° 36'	52'	York
44. Windham	43° 49'	70° 17'	220'	Cumberland
45. Yarmouth	43° 48'	70° 11'	68'	Cumberland
46. York	43° 11'	70° 42'	40'	York

Table B5. Northern Maine Zone station geographic information.

Location	Latitude	Longitude	Elevation	County
1. Caribou	46° 52'	68° 01'	624'	Aroostook
2. Flagstaff	45° 15'	70° 27'	1400'	Somerset
3. Fort Fairfield	46° 50'	67° 48'	415'	Aroostook
4. Fort Kent	47° 15'	68° 36'	500'	Aroostook
5. Greenville	45° 28'	69° 35'	1032'	Piscataquis
6. Houlton	46° 08'	67° 50'	410'	Aroostook
7. Kineo	45° 42'	69° 44'	1060'	Piscataquis
8. Millinocket	45° 39'	68° 42'	388'	Penobscot
9. Monson	45° 17'	69° 30'	1100'	Piscataquis
10. Presque Isle	46° 49'	68° 00'	606'	Aroostook
11. Ripogenus Dam	45° 53'	69° 15'	965'	Piscataquis
12. Van Buren	47° 09'	67° 56'	510'	Aroostook
13. Williamsburg	45° 21'	69° 51'	510'	Piscataquis

Table B6. Southern Interior Maine Zone station geographic information.

Location	Latitude	Longitude	Elevation	County
1. Augusta	44° 16'	69° 48'	450'	Kennebec
2. Bangor	44° 48'	68° 49'	163'	Penobscot
3. Buckfield	44° 15'	70° 20'	300'	Oxford
4. Carmel	44° 47'	69° 00'	175'	Penobscot
5. Cornish	43° 48'	70° 49'	778'	York
6. Dexter	44° 55'	69° 32'	310'	Penobscot
7. East Corinth	45° 01'	69° 01'	300'	Penobscot
8. East Wilton	44° 16'	69° 48'	415'	Franklin
9. Exeter	44° 57'	69° 14'	310'	Penobscot
10. Farmington	44° 40'	70° 09'	368'	Franklin
11. Foxcroft	45° 12'	69° 13'	338'	Piscataquis
12. Fryeburg	44° 03'	70° 45'	420'	Oxford
13. Gardiner	44° 10'	69° 45'	70'	Kennebec
14. Hallowell	44° 20'	69° 50'	300'	Kennebec
15. Hartland	44° 51'	69° 30'	200'	Somerset
16. Kennebec Arsenal	44° 16'	69° 48'	51'	Kennebec
17. Lee	45° 21'	68° 17'	408'	Penobscot
18. Lewiston	44° 06'	70° 14'	180'	Androscoggin
19. Madison	44° 48'	69° 54'	260'	Somerset
20. Mechanic Falls	44° 06'	70° 03'	500'	Androscoggin
21. Medford	?	?	285'	Somerset
22. Minot	44° 07'	70° 15'	400'	Androscoggin
23. North Belgrade	44° 30'	69° 49'	275'	Kennebec
24. North Bridgton	44° 03'	70° 45'	300'	Cumberland
25. North Palermo	44° 05'	69° 05'	600'	Waldo
26. Norway	44° 10'	70° 35'	383'	Oxford
27. Old Town	44° 56'	68° 39'	106'	Penobscot

Table B6. Continued

Location	Latitude	Longitude	Elevation	County
28. Orono	44° 52'	68° 42'	115'	Penobscot
29. Otisfield	44° 05'	70° 35'	310'	Cumberland
30. Oxford	44° 18'	70° 33'	182'	Oxford
31. Paris	44° 15'	70° 30'	380'	Oxford
32. Piscataquis	45° 10'	69° 30'	350'	Piscataquis
33. Rumford	44° 33'	70° 33'	505'	Oxford
34. Vanceboro	45° 34'	67° 26'	390'	Washington
35. Waterville	44° 46'	69° 38'	112'	Kennebec
36. West Waterville	44° 45'	69° 40'	125'	Kennebec
37. Winslow	44° 43'	69° 38'	90'	Kennebec
38. Woodland	45° 09'	67° 24'	140'	Washington

Table B7. Central Massachusetts Zone station geographic information.

Location	Latitude	Longitude	Elevation	County
1. Amherst	42° 24'	72° 32'	210'	Hampshire
2. Andover	42° 38'	71° 06'	264'	Essex
3. Baldwinville	42° 37'	72° 05'	827'	Worcester
4. Blue Hill	42° 12'	71° 06'	640'	Suffolk
5. Canton	42° 08'	71° 10'	250'	Norfolk
6. Clinton	42° 24'	71° 41'	370'	Worcester
7. Concord	42° 27'	71° 22'	139'	Middlesex
8. Deerfield	42° 31'	72° 37'	175'	Franklin
9. Dudley	42° 02'	71° 58'	705'	Worcester
10. Fitchburg	42° 36'	71° 50'	625'	Worcester
11. Framingham	42° 17'	71° 25'	172'	Middlesex
12. Franklin	42° 05'	71° 24'	320'	Norfolk
13. Grafton	42° 12'	71° 40'	425'	Worcester
14. Greenfield	42° 36'	72° 36'	200'	Franklin
15. Groton	42° 36'	71° 35'	320'	Middlesex
16. Haverhill	42° 46'	71° 04'	30'	Essex
17. Holden	42° 21'	71° 51'	750'	Worcester
18. Holyoke	42° 12'	72° 36'	113'	Hampden
19. Lake Cochituate	42° 19'	71° 23'	150'	Middlesex
20. Lancaster	42° 28'	71° 41'	450'	Worcester
21. Lawrence	42° 41'	71° 10'	51'	Essex
22. Leichester	42° 15'	71° 55'	800'	Worcester
23. Lexington	42° 27'	71° 31'	200'	Middlesex
24. Lowell	42° 38'	71° 19'	100'	Middlesex
25. Ludlow	42° 12'	72° 29'	380'	Hampden
26. Lunenburg	42° 35'	71° 43'	450'	Worcester
27. Medfield	42° 11'	71° 18'	300'	Norfolk
28. Medway	42° 08'	71° 23'	320'	Norfolk
29. Mendon	42° 06'	71° 33'	422'	Worcester

Table B7. Continued

Location	Latitude	Longitude	Elevation	County
30. Monson	42° 06'	72° 19'	350'	Hampden
31. Needham	42° 17'	71° 14'	295'	Norfolk
32. North Attleboro	41° 59'	71° 23'	178'	Bristol
33. North Billerica	42° 37'	71° 17'	115'	Middlesex
34. Northampton	42° 19'	72° 38'	115'	Hampshire
35. Phillipston	42° 38'	72° 08'	600'	Worcester
36. Princeton	42° 27'	71° 52'	1050'	Worcester
37. Royalston	42° 40'	72° 12'	817'	Worcester
38. Rutland	42° 25'	72° 00'	1160'	Worcester
39. Shelburne Falls	42° 37'	72° 44'	470'	Franklin
40. Shirley	42° 36'	71° 40'	850'	Worcester
41. Shrewsbury	42° 17'	71° 42'	873'	Worcester
42. South Groton	42° 36'	71° 34'	300'	Middlesex
43. Southwick	42° 03'	72° 46'	265'	Hampden
44. Springfield	42° 06'	72° 35'	199'	Hampden
45. Sudbury	42° 46'	71° 21'	250'	Middlesex
46. Templeton	42° 35'	72° 07'	910'	Worcester
47. Turners Falls	42° 36'	72° 32'	187'	Franklin
48. Waltham	42° 25'	71° 16'	190'	Middlesex
49. Wendell	42° 28'	72° 30'	610'	Franklin
50. Westboro	42° 16'	71° 38'	296'	Worcester
51. Westfield	42° 07'	72° 45'	165'	Hampden
52. Weston	42° 22'	71° 18'	220'	Middlesex
53. Woburn	42° 31'	71° 12'	200'	Middlesex
54. Worcester	42° 16'	71° 52'	560'	Worcester

Table B8. Coastal Massachusetts Zone station geographic information.

Location	Latitude	Longitude	Elevation	County
1. Barnstable	41° 40'	70° 17'	25'	Barnstable
2. Beverly	42° 33'	70° 53'	78'	Essex
3. Boston	42° 22'	71° 02'	30'	Suffolk
4. Brewster	41° 47'	70° 02'	43'	Barnstable
5. Bristol	41° 54'	71° 06'	150'	Bristol
6. Brockton	42° 03'	71° 00'	80'	Plymouth
7. Cambridge	42° 23'	71° 07'	75'	Middlesex
8. Charleston	42° 22'	71° 02'	60'	Suffolk
9. Chestnut Hill	42° 21'	71° 04'	130'	Suffolk
10. Danvers	42° 34'	70° 56'	42'	Essex
11. Dedham	42° 15'	71° 10'	50'	Essex
12. East Bridgewater	42° 03'	70° 57'	142'	Plymouth
13. East Wareham	41° 46'	70° 40'	18'	Plymouth
14. Edgartown	41° 23'	70° 31'	20'	Dukes
15. Fall River	41° 42'	71° 10'	200'	Bristol

Table B8. Continued

Location	Latitude	Longitude	Elevation	County
16. Ft. Independence	42° 14'	71° 00'	5'	Suffolk
17. Ft. Sewell	42° 30'	70° 50'	32'	Essex
18. Ft. Warren	42° 19'	70° 55'	5'	Suffolk
19. Georgetown	42° 42'	71° 00'	225'	Essex
20. Gerry	42° 24'	71° 05'	125'	Middlesex
21. Gloucester	42° 36'	70° 36'	45'	Essex
22. Hingham	42° 13'	70° 53'	70'	Plymouth
23. Hyannis	41° 40'	70° 17'	50'	Barnstable
24. Ipswich	42° 40'	70° 52'	80'	Essex
25. Kingston	42° 00'	70° 45'	65'	Plymouth
26. Lynn	42° 28'	70° 56'	70'	Essex
27. Middleboro	41° 53'	70° 55'	50'	Plymouth
28. Milton	42° 15'	71° 06'	100'	Norfolk
29. Nantucket	41° 15'	70° 04'	43'	Nantucket
30. New Bedford	41° 39'	70° 55'	100'	Bristol
31. Newbury	42° 45'	70° 55'	25'	Essex
32. Newburyport	42° 49'	70° 52'	46'	Essex
33. Newton	42° 21'	71° 11'	50'	Middlesex
34. Norfolk	42° 15'	71° 10'	180'	Norfolk
35. Plymouth	41° 57'	70° 40'	25'	Plymouth
36. Provincetown	42° 05'	70° 13'	40'	Barnstable
37. Randolph	42° 10'	71° 02'	311'	Norfolk
38. Raynham	41° 50'	71° 08'	150'	Bristol
39. Rockport	42° 39'	70° 36'	80'	Essex
40. Roxbury	42° 20'	71° 04'	629'	Sufflok
41. Salem	42° 31'	70° 55'	46'	Essex
42. Sandwich	41° 45'	70° 30'	20'	Barnstable
43. Somerset	41° 47'	71° 08'	40'	Bristol
44. Swampscot	42° 28'	70° 55'	45'	Essex
45. Taunton	42° 54'	71° 04'	41'	Bristol
46. Thatcher's Island	42° 38'	70° 35'	48'	Essex
47. Topsfield	42° 38'	70° 57'	60'	Essex
48. Vineyard Haven	41° 27'	70° 35'	15'	Dukes
49. Watertown	42° 21'	71° 10'	45'	Middlesex
50. Watertown Arsenal	42° 21'	71° 10'	45'	Middlesex
51. Wenham	42° 36'	70° 53'	57'	Essex
52. West Bridgewater	42° 15'	71° 01'	52'	Essex
53. West Dennis	41° 40'	70° 11'	25'	Barnstable
54. West Newton	42° 21'	71° 17'	55'	Middlesex
55. Weymouth	42° 10'	70° 58'	150'	Norfolk
56. Woods Hole	41° 30'	70° 40'	20'	Barnstable

Table B9. Western Massachusetts Zone station geographic information.

Location	Latitude	Longitude	Elevation	County
1. Adams	42° 39'	73° 06'	750'	Berkshire
2. Beane Mountain	42° 40'	73° 10'	3200'	Berkshire
3. Becket	42° 20'	73° 05'	1200'	Berkshire
4. Cummington	42° 27'	72° 54'	800'	Hampshire
5. Florida	42° 40'	73° 00'	2500'	Berkshire
6. Heath	42° 40'	72° 49'	1500'	Franklin
7. Hinsdale	43° 27'	73° 07'	1360'	Berkshire
8. Hoosac Tunnel	42° 41'	72° 58'	800'	Berkshire
9. Mount Tom	?	?	1400'	Berkshire
10. North Adams	42° 37'	73° 07'	710'	Berkshire
11. Pittsfield	42° 27'	73° 15'	1050'	Berkshire
12. Richmond	42° 23'	73° 22'	1190'	Berkshire
13. Rowe	42° 38'	73° 00'	1600'	Franklin
14. South Egremont	42° 09'	73° 27'	840'	Berkshire
15. Stockbridge	42° 17'	73° 19'	850'	Berkshire
16. Williamstown	42° 42'	73° 13'	725'	Berkshire

Table B10. Northern New Hampshire Zone station geographic information.

Location	Latitude	Longitude	Elevation	County
1. Benton	44° 02'	71° 56'	1200'	Grafton
2. Berlin	44° 29'	71° 10'	1110'	Coos
3. Berlin Mills	44° 16'	71° 16'	1011'	Coos
4. Bethlehem	44° 17'	71° 42'	1440'	Grafton
5. Errol	44° 47'	71° 08'	1260'	Coos
6. First Connecticut Lake	45° 05'	71° 17'	1660'	Coos
7. Grafton	43° 34'	71° 57'	840'	Grafton
8. Groveton	44° 36'	71° 31'	881'	Coos
9. Littleton	44° 18'	71° 46'	772'	Grafton
10. Mount Washington	44° 16'	71° 18'	6285'	Coos
11. Pinkham Notch	44° 16'	71° 15'	2029'	Coos
12. Pittsburg	45° 03'	71° 23'	1350'	Coos
13. Shelburne	44° 23'	71° 06'	700'	Coos
14. Stratford	44° 40'	71° 35'	950'	Coos
15. Whitefield	44° 23'	71° 37'	1332'	Coos

Table B11. Southern New Hampshire Zone station geographic information.

Location	Latitude	Longitude	Elevation	County
1. Alstead	43° 10'	72° 25'	1120'	Cheshire
2. Amoskeag	43° 06'	71° 36'	186'	Hillsborough
3. Antrim	43° 00'	71° 55'	608'	Hillsborough
4. Auburn	42° 59'	71° 23'	305'	Rockingham
5. Bedford	42° 55'	71° 32'	500'	Hillsborough
6. Boscawen	43° 19'	71° 37'	450'	Merrimack
7. Bristol	43° 36'	71° 43'	555'	Grafton
8. Canterbury	43° 22'	71° 33'	500'	Merrimack
9. Chichester	43° 16'	71° 20'	400'	Merrimack
10. Claremont	43° 23'	72° 20'	539'	Sullivan
11. Concord	43° 12'	71° 30'	346'	Merrimack
12. Contooksville	43° 15'	71° 30'	450'	Merrimack
13. Dover	43° 12'	70° 53'	150'	Stafford
14. Dublin	42° 55'	72° 04'	1869'	Exeter
15. Dunbarton	43° 06'	71° 35'	350'	Merrimack
16. Durham	43° 08'	70° 56'	123'	Strafford
17. Epping	43° 02'	71° 03'	140'	Rockingham
18. Exeter	42° 59'	70° 57'	125'	Rockingham
19. Farmington	43° 20'	71° 00'	300'	Strafford
20. Francestown	42° 59'	76° 25'	830'	Hillsboro
21. Franklin	43° 28'	71° 39'	430'	Merrimack
22. Ft. Constitution	43° 05'	70° 41'	8'	Rockingham
23. Hampton Falls	42° 57'	70° 50'	100'	Rockingham
24. Hanover	43° 42'	72° 17'	605'	Grafton
25. Hawke	43° 00'	71° 30'	450'	Hillsboro
26. Keene	42° 56'	72° 17'	490'	Cheshire
27. Londonderry	42° 53'	71° 25'	280'	Rockingham
28. London Ridge	43° 20'	71° 25'	475'	Merrimack
29. Manchester	43° 00'	71° 28'	300'	Hillsboro
30. Marlborough	42° 52'	72° 12'	400'	Cheshire
31. Mill Village	?	?	?	Hillsboro
32. Nashua	42° 48'	71° 29'	125'	Hillsboro
33. New Found Lake	43° 40'	71° 45'	555'	Grafton
34. Newmarket	43° 02'	70° 56'	50'	Rockingham
35. Plymouth	43° 46'	71° 40'	560'	Grafton
36. Portsmouth	43° 04'	70° 47'	40'	Rockingham
37. Sanbomton	43° 30'	71° 41	830'	Belknap
38. Somerworth	43° 15'	70° 50'	300'	Strafford
39. South Antrim	43° 03'	71° 57'	676'	Hillsboro
40. Stratham	43° 02'	70° 58'	100'	Rockingham
41. Tamworth	43° 50'	71° 15'	450'	Carroll
42. Wakefield	43° 34'	71° 00'	400'	Carroll
43. Weare	43° 05'	71° 44'	720'	Hillsboro
44. Weirs	43° 36'	71° 30'	750'	Belknap

Table B12. Rhode Island Zone station geographic information.

Location	Latitude	Longitude	Elevation	County
1. Block Island	41° 10'	71° 35'	110'	Washington
2. Bristol	41° 40'	71° 16'	55'	Bristol
3. Chepachet	41° 54'	71° 40'	165'	Providence
4. Dutch Island	41° 31'	71° 11'	76'	Newport
5. Fort Adams	41° 30'	71° 19'	37'	Newport
6. Kingston	41° 29'	71° 32'	166'	Washingtron
7. Manton	41° 46'	71° 30'	180'	Providence
8. Narragansett Pier	41° 26'	71° 28'	22'	Washington
9. Newport	41° 32'	71° 18'	75'	Newport
10. Nyatt Point	41° 44'	71° 20'	30'	Bristol
11. Providence	41° 50'	71° 25'	30'	Providence
12. Smithfield	41° 52'	71° 33'	150'	Providence

Table B13. Northeastern Vermont Zone station geographic information.

Location	Latitude	Longitude	Elevation	County
1. Barnet	44° 20'	72° 06'	475'	Caledonia
2. Berkshire	44° 58'	72° 46'	125'	Franklin
3. Bloomfield	44° 55'	71° 38'	1200'	Essex
4. Brookfield	44° 02'	72° 25'	1000'	Orange
5. Chelsea	43° 59'	72° 27'	870'	Orange
6. Coventry	44° 52'	72° 16'	718'	Orleans
7. Craftsbury	44° 35'	72° 22'	1100'	Orleans
8. East Barnet	44° 20'	72° 01'	760'	Caledonia
9. Enosburg	44° 52'	72° 45'	422'	Franklin
10. Garfield	44° 35'	72° 25'	1300'	Lamoille
11. Lunenburgh	44° 28'	71° 41'	1124'	Essex
12. Newbury	44° 07'	72° 05'	900'	Orange
13. Newport	44° 56'	72° 12'	750'	Orleans
14. Northfield	44° 08'	72° 40'	840'	Washington
15. Randolph	43° 55'	72° 40'	700'	Orange
16. Ryegate	44° 12'	72° 07'	730'	Caledonia
17. St Johnsbury	44° 25'	72° 01'	699'	Caledonia
18. Strafford	43° 52'	72° 24'	500'	Orange
19. Stowe	44° 28'	72° 41'	700'	Lamoille
20. Troy	44° 52'	72° 27'	850'	Orleans

Table B14. Southeastern Vermont Zone station geographic information.

Location	Latitude	Longitude	Elevation	County
1. Brattleboro	42° 57'	72° 34'	437'	Windham
2. Cavendish	43° 23'	72° 36'	800'	Windsor
3. Fayetteville (Newfane)	43° 00'	72° 38'	480'	Windham
4. Hartford	43° 40'	72° 22'	381'	Windsor
5. Hartland	43° 32'	72° 24'	665'	Windsor
6. Jacksonville	42° 48'	72° 49'	1890'	Windham
7. Norwich	43° 43'	72° 18'	795'	Windsor
8. Post Mills	43° 50'	72° 15'	472'	Orange
9. Vernon	42° 46'	72° 31'	225'	Windham
10. Westminster	43° 11'	72° 28'	350'	Windham
11. White River Junction	43° 39'	72° 19'	750'	Windsor
12. Windsor	43° 28'	72° 24'	700'	Windsor
13. Woodstock	43° 38'	72° 28'	650'	Windsor

Table B15. Western Vermont Zone station geographic information.

Location	Latitude	Longitude	Elevation	County
1. Bennington	42° 55'	73° 13'	670'	Bennington
2. Brandon	43° 48'	73° 05'	460'	Rutland
3. Burlington	44° 28'	73° 09'	332'	Chittenden
4. Castleton	43° 37'	73° 11'	500'	Rutland
5. Charlotte	44° 20'	73° 15'	90'	Chittenden
6. Cornwall	43° 58'	73° 12'	500'	Addison
7. Ferrisburgh	44° 15'	73° 15'	176'	Addison
8. Manchester	43° 10'	73° 04'	790'	Bennington
9. Middlebury	44° 01'	73° 15'	392'	Addison
10. Rupert	43° 15'	73° 12'	700'	Bennington
11. Rutland	43° 36'	72° 58'	475'	Rutland
12. St Albans	44° 48'	73° 10'	300'	Franklin
13. Wallingford	43° 28'	72° 59'	475'	Rutland
14. Wells	43° 27'	73° 14'	750'	Rutland