Climate of Vermont

Introduction

This publication consists of a narrative that describes some of the principal climatic features and a number of climatological summaries for stations in various geographic regions of the State. The detailed information presented should be sufficient for general use; however, some users may require additional information.

The National Climatic Data Center (NCDC) located in Asheville, North Carolina is authorized to perform special services for other government agencies and for private clients at the expense of the requester. The amount charged in all cases is intended to solely defray the expenses incurred by the government in satisfying such specific requests to the best of its ability. It is essential that requesters furnish the NCDC with a precise statement describing the problem so that a mutual understanding of the specifications is reached.

Unpublished climatological summaries have been prepared for a wide variety of users to fit specific applications. These include wind and temperature studies at airports, heating and cooling degree day information for energy studies, and many others. Tabulations produced as by-products of major products often contain information useful for unrelated special problems.

The Means and Extremes of meteorological variables in the Climatography of the U.S. No.20 series are recorded by observers in the cooperative network. The Normals, Means and Extremes in the Local Climatological Data, annuals are computed from observations taken primarily at airports.

The editor of this publication expresses his thanks to those State Climatologists, who, over the years, have made significant and lasting contributions toward the development of this very useful series.

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Topographic Features- ➢The Green Mountain State▶ covers 9,610 square miles, one-seventh of New England's total area. Though Vermont is the only New England state without a coastline along the Atlantic Ocean, most of its boundaries are water. The Connecticut River forms the border with New Hampshire to the east, while Lake Champlain marks over 100 miles of the western boundary with New York state. Vermont extends southward for about 160 miles from just north of 45° North to about 20 miles south of the 43rd parallel. The State widens northward from about 40 to 90 miles across.

Much of the terrain is hilly to mountainous, with a number of north-south mountain ranges, the most dominant of which is the Green Mountains. The northern Green Mountains area is higher in elevation than the southern section. Mt. Mansfield, the highest point in the State, at 4,393 feet above sea level, is found in the northern portion. The Champlain Valley is flat and undulating, while the topography of the Northeast Kingdom is hilly, it is not as rugged as the terrain of the Green Mountains. Many peaks in the Green Mountains rise to over 3,000 feet, as do several others in eastern Vermont. Elevations of less than 500 feet are mostly confined to the lowlands paralleling Lake Champlain in the west and to the central and southern portions of the Connecticut Valley in the east. Much of the State ranges from 500 to 2,000 feet in elevation. The State▶ s topography, lakes and soils bear the imprint of past glaciations. Inland waters cover more than 300 square miles.

Over 70 percent of Vermont is forested, distributed among federal, state, municipal and private reserves as well as farm woodlands. A considerable area, especially in the north, is sparsely settled. The mountains, hills, lakes, streams and forests combine to make Vermont a state noted for its scenic beauty.

Vermont shares with the other New England states: (1) changeableness of the weather; (2) large ranges of temperature, both daily and annually; (3) great differences between the same seasons in different years; (4) equable distribution of precipitation; and (5) considerable diversity from place to place. The regional climatic influences are modified in Vermont by varying elevations, types of terrain and distances from the Atlantic Ocean and Lake Champlain. The State has been divided into three climatological divisions: Northeastern (1), Western (2) and Southeastern (3). These divisions were derived to account for the main features of the aforementioned regional climate, with the realization that local climate variability and phenomena (such as frost hollows, snow summits juxtaposed with snow shadows) would not be captured.

Vermont lies in the "prevailing westerlies," the belt of generally eastward moving air which encircles the globe in middle latitudes between 30 and 60°. Embedded in this circulation are extensive masses of air originating in higher or lower latitudes which interact to produce low-pressure storm systems and fronts. Relative to most other sections of the country, a large number of such storms pass over or near Vermont. The majority of air masses affecting this State belong

to three types: (1) Cold, dry air pouring down from subarctic North America; (2) warm, moist air moving north-northeastwards on a long journey from the Gulf of Mexico and other subtropical waters; and (3) cool, damp air from the North Atlantic Ocean. Given the predominant air flow from the west, Vermont tends to be more influenced by the first two types than the third. The procession of contrasting air masses and the relatively frequent passage of "Lows" brings about on the average a twice-weekly alternation from fair to cloudy or stormy conditions, attended by often abrupt changes in temperature, moisture, sunshine, wind direction and speed. There is no regular or persistent rhythm to this sequence, and it is interrupted by periods during which the weather patterns continue the same for several days or infrequently for several weeks. Vermont weather, however, is cited for variety rather than monotony. Changeability is also one of its features on a longer time-scale. That is, the same month or season will exhibit varying characteristics over the years, sometimes in close alternation, and sometimes arranged in similar groups for successive years. A "normal" month, season or year is indeed the exception rather than the rule.

The basic climate, as outlined above, obviously does not result from the predominance of any single controlling weather regime, but is rather the integrated effect of a variety of weather patterns. Hence, weather averages in Vermont usually are not sufficient for important planning purposes without further climatological analysis.

The Western Division (3,177 square miles) is a relatively narrow band running the full length of the State west of the Green Mountains. This Division is least affected by Atlantic Ocean influences. Although its northern portion is moderated by Lake Champlain such that it is included with southwestern Vermont, storm tracks and moisture characteristics can differ between the northern and southern sections. The Northeastern Division (4,854 square miles) is the largest of the three and includes the northeastern, north-central and east-central portions of Vermont, with the exception of a narrow strip of the Connecticut River valley in the east-central portion. This strip is included as a part of the Southeastern Division (1,579 square miles) because of its lower elevation.

Temperature- The annual mean temperature is near 43 degrees Fahrenheit (° F) in the Northeastern Division; 44 in the Southeastern; and 46 in the Western. Averages vary also within the divisions. Elevation, slope, aspect and other local features, including urbanization, all have an effect. As an extreme example of the effect of altitude, a comparison between the station atop Mt. Mansfield's summit with the Enosburg Falls station is interesting. Though these stations are about the same distance from Lake Champlain, the average temperature is just above freezing at Mt. Mansfield while Enosburg Falls, at 3,500 feet lower elevation, is nearly 10 degrees warmer. The distance between the sites is about 25 miles. The State's highest temperature recorded is 105° F observed July 4, 1911 at Vernon; the lowest, -50° F, December 30, 1933, at Bloomfield.

Summer temperatures are comfortable as a rule and they are reasonably uniform over the State. Thirty-year averages for July remain around 66° F in the northeastern division, 69 in the western division and 67 to 68 in the southeast. Average daily minima reached in July are in the 50s over nearly the entire State. The average daily maxima reach near 80° F. Days with maxima of 90° F or higher average less than 10 per year at most stations. The frequency varies spatially and temporally, and tends to be greatest during drought years. In the coolest summers, days with

maximums equal to greater than 90° F range, in frequency of occurrence, from none at many stations to only a few at the warmest stations. In the warmest years many stations still have less than 10, but the frequency ranges up to as high as 30 at the warmer sites. Even after one of these hot days the temperature is likely to fall to 60° F or lower during the night. The average daily range is 20 to 30 degrees in summer, with the variation averaging a little more in the south than in the north. The diurnal range may reach 40° F or more during cool, dry weather in valleys and lowlands. A late spring or early fall freeze is a threat at a few of the more susceptible areas.

Temperatures from place to place vary more in winter than in summer. The Northeastern Division average in January is about 15° F, while for the Southeastern and Western Divisions it is near 19 and 18, respectively. The daily temperature range is less in winter than in summer, averaging near 20 degrees. Days with subzero readings during winter were common at most stations in the early half of the 20th century. They numbered from 10 to 40 per year in the southern portion and from 20 to 50 in the north. The number exceeded 60 at some stations in the coldest winters and could be less than 10 at other stations in the mildest winters. Conversely, winters since 1990 are among the warmest on record. At Burlington in the 1990s, monthly winter temperatures were 3.5 degrees above normal, with 1990 - 1999 containing the 7th - 10th warmest winters since the late 1800s.

The growing season for vegetation subject to injury from freezing temperatures averages 130 to 150 days in much of the Western Division and along the Connecticut River in the Southeastern Division. Lake Champlain exerts a moderating influence on the Champlain Valley portion of the western division where the growing season is the longest. Elsewhere the season varies from 100 to 130 days. Local topography causes exceptions and some localities have growing seasons as short as 80 to 90 days. The growing season begins in May and ends in September for most of the State.

Precipitation- Vermont's precipitation is well distributed through the year. The summer months ordinarily receive adequate amounts for growing crops over the entire State. Winter precipitation is noticeably less than summer rainfall in the northern and western portions of the State. This difference is greater in those areas than in any other part of New England. New England as a whole is noted for the even distribution of its precipitation throughout the year, an effect due to the influence of the Atlantic Ocean. This ocean influence is still strongly felt in southeastern Vermont, but it becomes weaker with increasing distance from the ocean. Low-pressure or frontal systems are the principal year-round moisture producers. When this activity ebbs somewhat in summer, thunderstorm bands or patches increase, more than making up the difference. Though brief and often of small extent, the thunderstorms produce the heaviest local rainfall intensities. They sometimes cause minor washouts of roads and soil erosion. High rainfall intensities also result from orographic enhancement, as storm cells are forced to rise by the complex and rugged topography. Rains of one to two inches in an hour can be expected at least once in a 10-year period. Frequency of days with measurable precipitation is between 120 and 160 days per year. As much as six inches of rain in 24 hours is rare in Vermont. Although, most stations have never recorded that much in a single day, stagnant storm systems or intense tropical cyclonic remnants have been responsible for such totals in Montgomery in July 1997 and in Somerset (8.77 inches in 24 hours) during the flood of November 1927.

Variations in monthly totals can be extreme, ranging from none to over 10 inches, but such large fluctuations are rare. Most of the monthly totals fall in the range of from 50 to 200 percent of normal. Very severe droughts rarely occur in Vermont, but when they do, the entire State is affected for a number of years. Among these, the droughts of the mid-1960s were of particular note in terms of their severity and duration. More recent droughts have plagued the State in 1994 - 1995, 1998 - 1999 and 2001 - 2002 with the latest being most reminiscent of the mid-1960s. Less severe droughts are more common and localized in spatial extent. There has been a shift in marked tendency for these to occur between the southeastern and western divisions. Drought impacts are felt by individuals, forests, agriculture, tourism, utilities and other sectors that rely on surface or groundwater supplies.

Droughts and floods tend to follow each other in Vermont. Both flooding and flash flooding (which is characterized by its rapid onset and high intensity) have become pervasive hazards. They were the source of the majority of the Presidential Disaster Declarations between 1970 and 2002. Flooding triggers are seasonal in nature and include consecutive large storms, ice jams, snowmelt, rain on frozen ground, saturated soils and tropical cyclones or their remnants. Many of these events tend to occur in preferred parts of the State (e.g. in the Jay Peak-Lowell area) because the topography is conducive. Widespread flooding caused by torrential rains November 2 - 3, 1927, produced flood damage estimated at $26 million (1927 figure). This remains the flood of record on many rivers across the State.

The mean annual runoff in the streams ranges from about 10 inches in portions of the Lake Champlain drainage to 40 inches in southern Vermont. The Connecticut River forms the eastern border and its tributaries drain the major portion of Vermont. In the northwest portion, rivers drain into Lake Champlain or directly into the St. Lawrence. A small area in southwest Vermont drains into the Hudson River.

Total annual precipitation averages about 45 inches in the Southeastern Division and nearly 38 inches in the other divisions. Individual means vary considerably from station to station, especially within the Southeastern Division. Bellows Falls, with less than 41 inches per year, and Searsburg Station, with 56 inches, are less than 30 miles apart. The mountainous character of much of the State accounts for much of the variability from place to place.

Occasionally freezing rain occurs, coating exposed surfaces with ice. Most areas can expect at least one such occurrence in a winter. The ice storm of January 1998, which has been estimated to have a return period of 400 years, was the most devastating icing event in recent history. Accumulations of one to three inches across parts of northern Vermont (Northeast Kingdom, Connecticut River valley, Champlain Valley) and surrounding states and provinces produced marked forest injury and utility line damage. Milk production was also severely disrupted. In view of this infrequent, but high intensity hazard, possible ice load should be considered when designing structures such as steel towers. The ice load also magnifies the wind stress by increasing the area exposed to the wind.

Average annual total snowfall ranges from 55 to 65 inches in much of the Western Division and also in parts of the Connecticut River valley. Elsewhere the annual averages vary greatly. Amounts range upward to as much as 100 inches and, at a few stations such as Jay Peak with

over 150 inches. Topographic differences cause large variations over short distances. As a result, snow summits and snow shadows can be found within a few miles of each other. As an example, Bennington has about 55 inches of snow per year, while Somerset, with over 120 inches, is located only about 15 miles away, but at a much higher elevation.

Snowfall is highly variable from place to place, as well as from season to season, with variations being observed for the same month in different years. Variations in seasonal totals are mostly from about 50 to 150 percent of the long-period average. The snowiest winters on record since the 1800s occurred from 1968 - 1969 to 1971 - 1972. It is interesting to note that one of the snowiest winters on record in the 20th century (1965 - 1966) occurred during the multi-year drought mentioned earlier. Totals for the least snowy seasons range from 25 to 50 percent of the greatest seasonal amounts. Month to month variations are much greater. This seasonal and monthly variability are sometimes coupled with the tendency of one extreme to follow another. Thus, at Burlington, the September 1999 - January 1, 2000 period was the least snowy, only to be followed by April 2000 being the second snowiest April on record.

Snow storms can be produced by "Nor'easters", blizzards, lake-effect snows, mountain-induced events or frontal systems. Nor▶easters can produce widespread damage as occurred on December 26 - 28, 1969 when statewide snow totals were up to three feet. Their frequency also varies, with the winter of 2000 - 2001 being a high frequency season during which new snowfall records were set (e.g. 22.9 inches on March 5 - 6 at Burlington). The average number of days with an inch or more of snowfall in a season varies from near 20 to 40, with the frequency increasing with elevation. Most winters have several snowstorms of five inches or more. Storms of this magnitude may temporarily disrupt transportation. On the other hand, large snow storms in October/November or March/April have been viewed as a boon by the ski industry since the skiing season is thereby lengthened.

Blizzards are also common occurrences. The Great Blizzard of 11 - 14 March 1888 was notable for the extreme temperatures, deep snowfall and gale force winds. Amounts in the southwestern part of the State ranged from 40 to 50 inches and in the southeastern part, from 30 to 40 inches. Drifts 15 to 40 feet high were reported. Most of northern Vermont received from 20 to 30 inches in this storm. However, snowfalls of 20 inches or more are unusual in any part of the State. The heaviest 24-hour falls of record at many stations do not exceed 25 inches, although St. Johnsbury recorded 33 inches on February 25, 1969.

Snow cover is continuous in Vermont throughout the winter season as a rule. January thaw is a well-known climate singularity (or meteorological event that tend to occur around a given date) in Vermont. The thaw now occurs around January 21, although in the early 1900s it could have taken place during a period from the last week of December to the middle of February. Thaws do not occur during severe winters. The depth of snow on the ground reaches its maximum for much of the State in the latter part of February. At the highest elevations, however, this date falls in the middle of March. Water stored in the snow is an important contribution to the water supply, although it should be noted that very snowy winters raise the increased threat of snowmelt-related flooding in the spring.

Sunshine averages near 50 percent of possible on a year-round basis, but varies with topography.

Data are only collected at few sites and are therefore insufficient to describe statewide characteristics in detail. Higher elevations and peaks are cloudier, especially in winter, probably reducing the percentage to as low as 40 in local areas. Sunshine is most abundant during the summer season.

Heavy fog varies remarkably with location and topography but, again, not enough data are available to describe this in detail. Persistent fogs are sometimes experienced at higher elevations. The duration of fog diminishes over flat and valley locations. The shorter duration heavy ground fogs of early morning occur frequently at susceptible places in these areas. The number of days with fog varies from 10 to 60 per year over the State, except even more on the highest mountain peaks.

Vermont lies in the region of prevailing westerlies, with the wind coming from the northwest in winter, and from the southwest in the warmer part of the year. The rugged topography has a strong influence on the direction of the wind at the meso- and local scale, such that, many areas have prevailing winds that blow parallel to a valley. The major valleys tend to lie in a north-south direction. Thus prevailing winds may be from the north in winter and from the south in the warmer seasons in those areas.

One type of wind that is indigenous to Vermont is gravity or fall winds called shirkshires. These damaging winds can gust to hurricane speeds (74 mph) and gain speed as they are funneled through the Valley of Vermont between the Green Mountains and the Taconics in southwestern Bennington County.

Storms of tropical origin may occasionally affect Vermont in summer or fall, bringing a double-edged sword. Like many of the climatic features already discussed, the frequency and type of impacts of these storms have varied from decade to decade and century to century. Their influence on Vermont was particularly common in the 1950s and 1990s. They serve a positive role in that the accompanying precipitation has often helped to reverse or end an ongoing drought, as occurred most recently in 1988 (Tropical Storm Chantal), 1995 (Hurricane Opal) and 1999 (Hurricane Dennis and Tropical Storm Floyd). However, when tropical cyclones or their remnants produce rainfall on saturated ground (as occurred in November 1927), catastrophic flooding occurs. Wind-related damage is also of concern. As trees fall, utility failures and property damage occurs.

Tornadoes tend to occur with severe thunderstorms and produce relatively localized damage. Although not a common phenomenon, reports of tornadoes were quite frequent in the 1960s, but became quite rare by the 1990s. On the average, only one of these most violent storms occurs each year. Historical accounts suggest that the most notable Vermont tornado occurred on June 23, 1782. Entering the southwest corner of the State, it traveled northward and eastward and crossed into New Hampshire near Weathersfield. Fortunately, most tornadoes are very small and weak (F0 or F1 on the Fujita scale). With the exception of Grand Isle, Caledonia and Washington counties, each of Vermont▶ s 14 counties have been struck since 1950. Annual damage estimates in 1999 dollars are $241,600. An F2 tornado occurred in Bennington County on May 31, 1998 producing $630,000 in property damage as well as power outages. About 73 percent of tornadoes occur between May 15 and September 15. About 78 percent strike between

2:00 p.m. and 7:00 p.m. The peak months are June and July and the peak hour is 5:00 p.m. to 6:00 p.m. The chance of a tornado striking any given spot is extremely small.

Thunder and hailstorms also have a frequency maximum from mid-spring to early fall. Thunderstorms occur on 20 to 30 days per year. The most severe are attended by hail, which can also be associated with tornadoes. Hail can damage or even ruin field crops and apple orchards, break glass, dent automobiles and damage other vulnerable exposed objects.

Climate and the Economy- Activities in Vermont are profoundly influenced by climate. Tree growth is especially favored. Covering over 70 percent of the area, forests are a major scenic attraction. The spectacular colors in the autumn draw countless visitors. Lumbering and related wood products are leading industries. The ample supply of rainfall provides not only for timber growth but also the huge amount of water required in making of paper and other manufactures. Industries include quarrying and the manufacturing of machinery, textiles and glass products. A great many other interests take advantage of the abundant water supply. A large portion of the State's electrical power comes from a well developed hydroelectric system. Moisture extremes (drought and flooding) produce significant impacts on any socioeconomic sector that relies on surface or groundwater supplies.

Climate is a significant factor in Vermont agriculture. Principal farm specialties include dairying, poultry raising, arboriculture, truck gardening and Christmas trees. Fresh milk and milk products are among the leading farm outputs. Apples are the most prolific of the tree fruits, with quality production an important commercial pursuit. Apples are very sensitive to temperature variations and the varieties that thrive today are those that weathered the severe winter of 1917 - 1918. Vermont is the leading state in top quality maple syrup and maple sugar production. Abundant snowfall also benefits the sugar maple industry by providing a protective cover for the root systems so that sap production is enhanced in the spring. Strawberries are an important truck product while a large acreage is devoted to pasture and hay, and to oats and corn.

Climate is particularly important to the tourist and vacation industries. Summer camps abound on the shores of many of the State's 400 lakes and ponds. Abundant game and lakes and streams draw sports enthusiasts from far and near. Skiing, with related winter sports, is a very important seasonal attraction made possible by the abundant snowfall.