P1.2 DEVELOPING CLIMATE STATION HISTORIES FOR PRE-20th CENTURY U.S. OBSERVING SITES

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INTRODUCTION

The climatological community has long desired the use of digital long-term observational data from the earliest records taken in the U.S.. This dream is becoming a reality under the auspices of the National Oceanic and Atmospheric Administration's Climate Database Modernization Program (CDMP). The CDMP is managed by the National Climatic Data Center in partnership with the Regional and State Climate Centers. The primary focus is to extend the current digital database which begins in 1948, by keying (manual data entry) climate observations recorded at U.S. military and civilian stations since the late 1700s.

One of the benefits of a historical digital climate record is its usefulness in addressing the complex issues of long-term climate trends and natural climate variability. Complementary to such analyses are the ancillary information about the data themselves, i.e. the station histories, that are critical in determining data (in)homogeneities and representativeness. The use of such ancillary data (including such details as station relocation, elevational differences etc.), while crucial, is hindered by the fact that no organized station histories were kept until the late 1800s. Part of the data recovery programs of the CDMP are devoted to discovering this ancillary information about individual stations using a variety of sources (such as the original observer forms). The information is then compiled into a coherent set of metadata suitable for ingesting into the official station history databases maintained by the state climate offices, regional climate centres and the National Climatic Data Center. This paper chronicles the findings and results of a joint effort to develop and document these station histories for the states of Vermont and Texas.

The CDMP represents the latest commitment to the preservation of long-term climate records. In 1952, the United States Weather Bureau's Climatological Record from 1819 to 1892 was placed on microfilm and catalogued in the National Archives. The data captured at that time included monthly and quarterly reports received by the Surgeon General from 1819 to 1859; monthly reports of volunteer observers for the Smithsonian Institution from 1849-1859; weekly and monthly reports of Signal Office and Weather Bureau stations from 1870 to 1892; and monthly reports from volunteer observers from the Signal Office and Weather Bureau from 1874-1892 (Records Management Service Job No. 29, 1952). All of these records have been re-scanned as part of the CDMP and will be available in digital format.

2. VERMONT

Burlington and Lunenburg, Vermont were the first two stations to be keyed as part of the CDMP initiative. They could not be more different in their histories, observers, elevations and type of observations made. Burlington is located on the eastern shores of Lake Champlain and comes under the moderating influence of this water body which is 19.32 km wide at its greatest extent. Observations continue to be made today at the Burlington International Airport. In contrast, Lunenburg (spelt Lunenburgh at the time of its status as an observing station) is located on the state's easternmost border, along the Upper Connecticut River that separates it from New Hampshire. Readings at this high altitude station (342.8 m or more) ended with the death of the main observer (Dr. Hiram A. Cutting) in 1892.

3. LOCATING THE METADATA

A variety of station history, instrument description and other forms of the U.S. Weather Bureau provided an initial starting point in the search for former observers/stations, their instrumentation and the conditions under which observations were acquired. The Weather Bureau forms which have already been scanned, were

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indispensable in telling the weather instrumentation story from the 1890s forward. In order to extend the ancillary database backwards, however, other historical accounts were needed. These took the form of weather entries in the personal diaries of individuals; a book written by Frank E. Hartwell of the Weather Bureau in 1958; a text about Burlington published in 1905; writings of the Dr. Hiram A. Cutting, the Lunenburgh observer; theses and other papers of the Historic Preservation Department of the University of Vermont; historical postcards, sketches, photographs, maps and topographic surveys housed in the Special Collections of the Bailey/Howe Library of the University of Vermont and; holdings at the Vermont Historical Society and the Lunenburg Historical Society. While these accounts and the pictoral evidence are fascinating in their own right, together paint a picture of what Vermont's weather was like in the pre-1948 era, not only in the towns of Burlington and Lunenburg, but across the entire state as well. For example, Hartwell's 1958 book reveals the intricacies of the relationship among the Weather Bureau, Canadian Colonial Airways and the airport, Burlington's economy and the University of Vermont.

4. BURLINGTON STATION HISTORIES

One of the most valuable components of the CDMP was the acquisition of a scanned copy of the daily records made by Burlington resident Zadock Thompson. These "Meteorological Observations made mostly at Burlington, VT in Latitude 44°28½'N and Longitude 73°11'W from Greenwich" begin in January 1832 and contain temperature and wind observations three times a day, as well as pressure values, water (i.e. precipitation), weather descriptions (clear, cloudy etc.) and other remarks. Thompson indicated that parts of the journal for 1829 were lost, while the years 1830 and 1831 are summarized in a paragraph each. The reason that the journal was entitled "mostly at Burlington, VT" was due to Thompson's relocation to Hartley, Québec on 1 January 1834. He discontinued regular journal entries until September 1836. On 10 June 1836, Thompson again relocated to Sherbrooke, Québec and readings for the rest of that year document conditions in the southeastern part of the province.

In January 1837, Thompson returned to Burlington and resumed his readings on the University of Vermont campus, 1.61 km east of Lake Champlain, at an elevation of 76.25 m above sea level. Journal entries on 10-11 June, 1843 indicate snow fell. In January 1850, the frequency of observations increased to 5 times a day (sunrise, 0700, 1300, 1400, 1900) for the variables of temperature, pressure, wind direction and speed, clouds (as oktas), snow presence and other remarks. In January 1855, the new readings of barometer corrected and operator thermometer were added. More significantly, observations times were changed to sunrise, 0700, 1200, 1300, 1400 and 2100. Following Thompson's last submission in December 1855, his widow Phebe Thompson continued the Burlington records on the new "Form of Meteorological Register prepared by the Smithsonian Institution for a uniform system of observations"until December 1856. It is interesting to note that Mrs. Thompson's forms indicate the station elevation to be 105.53 m about sea level. There were no records for 1857. In January 1858, N.K. Petty became the new Burlington observer submitting observations to the Smithsonian Institution at three intervals (0700, 1400 and 2100). The new station, while still on the University of Vermont campus, was now located at 111.94 m above sea level, with coordinates of 44°27'N, 73°10'W. Petty's observations ended in November 1864.

Like many of the early observers, Zadock Thompson compiled his observations into a published manuscript entitled "Natural History of Vermont", in 1853. In the mid-19th century, "very little damage is ever done by hurricanes and hail. The crops oftener suffer from an excess, than from a deficiency of moisture, though seldom from either" (Thompson, 1853:13). By the early twentieth century, tropical cyclone remnants had become both a boon (in helping to reverse droughts) as well as a bane (e.g. the Great Flood of 1927). Thompson's keen eye also noted the key characteristics of the Vermont landscape that make it prone to flash flooding, most notably the steep V-shaped valleys which help to constrain streamflow, producing fast-flowing walls of water.

The addition of Thompson and Petty's records begins to close the gap on an entry on the 1 December 1953 Weather Bureau Station History form that indicates an unknown location for Burlington readings from 1838 to 24 May 1871 when the U.S. Signal Corps opened a station in the U.S. Custom House City Hotel Block on the southeast corner of Church and Main Streets in downtown Burlington. From the 1871 Report of the Chief Signal Officer, we learn that the observations were made on the flat roof of this

building where the "exposure is good and the circulation of the air unobstructed". In addition to the wind-vane, anemometer and wind-gauge installed on the roof, an instrument shelter (housing a barometer, thermometer and hygrometer) was located outside the north window of the Signal Office's third floor location. The Signal Corps remained in this location until 4 August 1874, with the only variations being the moving of the anemometer and rain gauge to the middle of the building on 8 June 1871 and the adjustments in instrument height on 1 April 1873. On 4 August 1874, the Corps moved two city blocks north to the Fisher's Block on the southeast corner of Bank and Church Streets. Although details about this location are sketchy, the instrument elevation above the ground differed from the previous location. In January 1881, weather records were archived on a War Department, Signal Service U.S. Army form, with the times of observation being changed to AM, PM and midnight. The Corps' final relocation prior to closing the station on 15 June 1883, was to the Howard Opera House Block (Fig.1) directly across the street from Fisher's Block, i.e. on the southwest corner of Bank and Church Streets. The Opera House itself was 18.3m high and the original roof was made of tin and copper and painted red (Bryan, 1975). This represented the largest change in instrumentation height of all of the Corps' relocations. It is unclear whether John P. Howard's "donation of the entire Howard Block – stores, theatre, hall, and weather station– to the Home for Destitute Children" (Bryan, 1975:12), on 14 November 1881 precipitated the Signal Corps' relinquishing the station observations.

Fig. 1 Howard Opera House in late 1800s.

In October 1883, Walter Benton Gates began his responsibilities as a volunteer observer for the War Department Signal Service U.S. Army. He graduated from the University of Vermont in 1881 and was a reporter and the city editor of the Burlington Free Press newspaper from 1887. Gates also supervised the 1900 U.S. Census for Vermont (Kubly, 2003). Most currently available metadata/station history documents locate Gates' first address as City Hall Park. However, the newly scanned archived document indicate that Gates reported from 55 Elmwood Avenue (two blocks north of City Hall Park) from November 1883 to November 1891 when he moved to 57 Elmwood Avenue. Instrument height installations appear to be equivalent at both addresses which were estimated at 67.1 m above sea level. Observations were made at 0700, 1300 and 1900. Between 1892 and 1906, his other residences were given as 301 South Willard Street and 57 Sherwood Avenue. Relocations from Elmwood Avenue represent a move away from the central part of growing town of Burlington, to a more suburban setting higher in elevation and further removed from the shores of Lake Champlain. In the late 1800s, the "Description of Voluntary Observer's Station and Instruments" (Form 4029) of the Signal Service contained details on the instruments, their location and shelter and times of observation. From these we were able to glean that by the time of his final relocation, Gates' observations were taken at 1900 only in 1906.

On 17 April 1905, the University of Vermont donated a block of land that would later become 601 Main Street to the U.S. Government for the sole purpose of establishing a Weather Bureau office. Located at 121.4 m above sea level, the two-storey red brick building (Fig. 2) was completed in 1906 and observations began on 29 March of that year. The main floor was devoted to weather forecasters' office who had private quarters on the second floor. Instruments were mounted on the flat roof of the building, and weather balloons were also launched (and recovered) from there (Hammerstedt, 2003). Among the head forecasters at this site, Frank E. Hartwell should be mentioned in particular. A tropical meteorologist, he arrived in Burlington in May 1919 to investigate the possibility of pilot-balloon flights. The flat roof and lack of tall buildings or trees around 601 Main Street made this location ideal. Following his first winter in Vermont, Hartwell felt compelled to correct a number of erroneous misconceptions about the state's weather and climate, the result of which was a milestone piece on "The Climate and Weather of Vermont," that appeared in the Vermonter-The State Magazine in 1922. This

account has been useful in tracing the shifts in climate singularities such as the January thaw (Dupigny-Giroux, 2002) over the course of the last 100 years. During Hartwell's eleven-year stint in Burlington, which is well chronicled in his 1958 account of forty years in the Weather Bureau, we learn about the public's dependence upon the bureau for weather and climate information, in much the same way that State Climatologists function today.

Fig. 2 Weather Bureau Building 1907

The Weather Bureau was charged with making temperature, precipitation, humidity and wind observations at defined intervals and then relaying these by wire to a centralized office. The 601 Main Street location remained in operation until 4 June 1943 and provided an overlap in readings with the newer office that was established in the Old Administration Building (44°28'N, 73° 9'W) of the Burlington Municipal Airport on 1 March 1939. The Station History forms (Form 500-1) of the Weather Bureau in the early 1900s reflected the growing importance of weather data to aviation. These forms were supplemented by the Form 4065C which described the Meteorological Features and Instrumental Equipment and Exposures at Airport, Airway and 6-hourly stations. These chronicle instrument types, changes, mountings and locations, as well as visibility issues and features of the surrounding topography. For example, the 7 February 1934 entry detailed the need to install a 12-foot support on the beacon light tower to counteract the influence of the larger of the two hangars as well as some trees at the Burlington municipal airport. Related to these two forms is the Inspection of Airport and Airways Stations Instrument Equipment form (4064C). From the latter it was clear, that although temperature, humidity and pressure readings were being taken at the airport location in the early 1930s, wind and ceiling height information were collected at the building at 601 Main Street (some 4 km ESE of the airport) and transmitted by radio or telephone to the airport. Form 1144 on 1 January 1937 states that "All regular airway reports originate at the City Office...Only such observations as are needed for their own use are taken by the airport station." It was also interesting to note the symbiotic relationship between Canadian Colonial Airways and the Weather Bureau in terms of wind measurements in the 1930s.

On 16 February 1950, the Weather Bureau moved into the Administration Building at the municipal airport, which would become the Burlington International airport in April 1969. Essential operations had been transferred from the 601 Main Street location by the mid-1940s as the need for twenty-hour observations in the service of aviation occurred. The building at 601 Main Street then reverted to University of Vermont property in October 1951. At the airport, a number of new instruments were added and others relocated either to the airfield or roof. Overlapping, independent records were also made at the University of Vermont from December 1956 to June 1964. Finally, on 19 July 1973, the National Weather Service operations moved to the Terminal Building at the Burlington International Airport, where they remain today.

5. LUNENBURG STATION HISTORIES

The town of Lunenburg in southeastern Essex County, lies along the Connecticut River. There, the mountainous terrain increases in elevation as one moves westward towards the Green Mountains. Very different in character from the metropolitan Burlington station, Lunenburg's population peaked during the logging era in the late 1800s.

Dr. Hiram Adolphus Cutting served as the main volunteer observer in the town of Lunenburg from 1859 till his death on 18 April 1892 (Ludlum, 1996). The scanned CDMP record begins in 1859 with the months of February to June all entered on the same form. The initial instruments were provided by the newly created Smithsonian Institution as part of their national weather observing network. Cutting submitted his observations to the Smithsonian Institution until January 1876, after which the data were collected by the War Department Signal Service U.S. Army until August 1891. The Smithsonian Institution's Register of Meteorological Observations form had entries for pressure and temperature to be made at 0700, 1200 and 1900, with wind direction and force readings at 0700, 1400 and 2100. Dr. Cutting's readings were made at 0700, 1200 and 1900 for the first few years, with the switch to the standard times in February 1863. During the War Department era, observations were made at

0700, 1400, 2100 and midnight of variables such as temperature, rain and snow, upper and lower clouds, winds, pressure, humidity and dew points. In addition, the precision with which locations were recorded increased so that readings were made at 44°27'40"N, 71°40'47"W, instead of being rounded to the nearest minute. This precision was maintained when the data collected reverted on the Signal Service in September 1891.

In terms of changes in station location, two were documented on the Signal Service forms. Observations were made at 342.82 m above sea level until December 1872, at which time they were made at 369.1 m. This may coincide with the expansion of Dr. Cutting's holdings. With his background in agriculture, he was very interested in experimental farming and owned an over 80.94 hectare estate on which he grew mainly hay. The land was described as being upland and poor in quality until he applied the research that he famed for in his many lectures. He also owned a grist mill, shingle mill, planning mill and butter-tub factory. One other station change is gleaned from the ancillary data. On 1 January 1855, Cutting opened a store in Lunenburg with his uncle John G. Darling. In July 1866, the store was consumed by fire and his extensive scientific collection destroyed. By December 1867, he had re-established his commerce, with two additional wings adjoining the new store. Above one of these wings was his observatory from which he made his meteorological readings. From there Dr. Cutting kept wind direction and velocity measurements in addition to temperature, precipitation and snowfall records. He determined that the average annual snowfall in Lunenburg was 2184.4 mm with an annual rainfall of 1046.2 mm (Bibliographical Encyclopaedia of Vermont of the Nineteenth Century, 1885).

Born in the neighbouring town of Concord, Vermont on 23 December 1832, Dr. Hiram A. Cutting was a man of boundless energy, interests and determination. At 14 he was a land surveyor and by age 16 was teaching in a district school in Essex County. His passion was medicine and although he began these studies at 15, ill health among other factors caused him to put them aside until 1870. On 3 November 1870, he was presented with the diploma of M.D. from Dartmouth College after his professor (E.E. Phelps) declared that Cutting was more knowledgeable than he. An honorary Doctor of Philosophy degree followed in 1879 from Norwich University in recognition of his scientific merits. An avid scientist with wide ranging interests from botany, human anatomy, agriculture, insects, geology and the atmosphere, Dr. Cutting's legacy includes texts on "Plant Growth and Fertilization," "Ventilation of Farm Homes," "Climatology of Vermont" and "Notes on a Hailstorm in Concord." Among the many positions that he held, Dr. Cutting served as the Notary Public, Examining Surgeon, State Curator of Natural History, State Geologist, Board of Agriculture as well as chairing the Fish Commission of Vermont (Bibliographical Encyclopaedia of Vermont of the Nineteenth Century, 1885).

The CDMP digital archive revealed that a second observer, Edson S. Cassino also made observations in Lunenburg from September to November 1872 at 44°28'N, 71°42'W and at an elevation of 300.7 m. A comparison of the higher elevation Cutting data would allow for the identification of cold or frost hollows which are common in Vermont, as cold air drainage and differential heating of the slopes causes significant variations between stations that are quite proximate.

Finally, although the observations end at Lunenburg in April 1892, other cooperative stations have continued to document the variability of the region. These include Stratford, New Hampshire, Bloomfield, Vermont (which closed in 1968 and which holds the record for the lowest temperature observed in the state at -45.5°C) and West Burke (Ludlum, 1996).

6. USING PHOTOGRAPHIC EVIDENCE - THE TEXAS SETTING

To date, few photographs or sketches have been found of the actual instruments used at the two sites in Vermont. For the sake of comparison, the findings from Austin Texas will be briefly described to demonstrate the ways in which the written ancillary records can be complemented by photographic evidence.

The photographic record of the instruments at this site begins in 1917 with University of Texas campus location. The instruments were installed on the roof of the Engineering Building in a rather rural setting. By March 1932, the observing site had moved to downtown Austin on the roof of a nine-storey structure, the Littlefield Building (Fig. 3) and thence to the roof of the U.S. Court House by November 1936. The site remained relatively unchanged until 1942 when it moved to the

airport. The unobstructed exposure of the instruments at ground level is clearly evident in the 1943 photograph.

Figure 3. Instrument shelter and gauges on the roof of the WBO on the Littlefield Building in Austin, TX in March 1942.

8. FUTURE ANALYSES

As the data are keyed and quality controlled, they are then placed in the WSSRD online system. In extending the existing digital record beyond the 1948 period, two key avenues of research will open up to atmospheric scientists and other interested in long term climate variability and changes. The first involves data continuity issues. As noted above, some of these historical observations overlap with existing long-term stations, allowing for station comparisons in order to distinguish the contributions of elevation and exposure changes in the record. The second stream would include the examination of historical trends and extremes. Detailed analyses of the Year without a summer (1816), the droughts and cold spells of the 1800s and the Great Blizzard of 1888 would be possible.

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Acknowledgments: The authors would like to thank Adam Hillman and the staff at the Bailey/Howe Library of the University of Vermont for their invaluable assistance in the ancillary data collection.