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ABSTRACT

Meteorological conditions have been recorded at the summit of Mount Washington, New Hampshire, (44°16′N, 71°18′W, 1914 m ASL) since November 1932. Use of consistent instrumentation allows analysis of humidity measurements as calculated from error-checked dry bulb temperature, wet bulb temperature, and pressure during the period 1935–2004. This paper presents seasonally and annually averaged dewpoint temperature, mixing ratio, and relative humidity means and trends, including clear-air and fog subsets and, beginning in 1939, day and night subsets. The majority of linear trends are negative over the full study period, although these decreases are not constant, with relatively large (small) values in the mid-1950s (late 1970s). Annual mean dewpoint (water vapor mixing ratio) over the 70-yr period has decreased by 0.06°C decade⁻¹ (0.01 g kg⁻¹ decade⁻¹). During this period the annual frequency of fog increased by 0.5% decade⁻¹. Dewpoint and mixing ratio trends, both generally decreasing, differ by season; they are smallest in spring and greatest in fall. Relative humidity has decreased most in winter. The clear-air subset shows significant decreases in both dewpoint and mixing ratio for all seasons except spring.

1. Introduction

Atmospheric water vapor is a key component of the global hydrological cycle. As the most important “greenhouse” gas, changes in its concentrations influence the climate directly via absorption of radiation and indirectly through the formation and evolution of clouds. Increasing global temperature is expected to lead to increasing water vapor concentration as warmer air masses have higher saturation vapor pressures. Water vapor plays an important role in regional and local hydrological cycles. Changes in water availability, in addition to temperature, have had broad impacts on the composition of the forests of New Hampshire (Shuman et al. 2004, 2005). Water vapor plays an especially important role in mountainous areas via changes in precipitation, cloud amount and height, and water deposition from cloud droplet interception (Richardson et al. 2003). Increased clouds can lead to changes in ecosystem primary production and species composition (Mallinson and Cairns 1995), while changes in rime-deposited water may alter the boundaries of the spruce–fir zone and the transition to tundra (Richardson et al. 2004). Deposition of cloud water in summer and rime ice in winter likely influences the alpine...
Recent water vapor analyses and trends for the northeastern United States

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Table 1. A summary of recent water vapor studies with data type, time period, variables reported, spatial cover, and generalized local trend in water vapor for the northeastern United States. Variables are vapor pressure ($e$), precipitable water from surface to 500 mb ($W$), mixing ratio ($r$), specific humidity ($q$), relative humidity (RH), and dewpoint temperature ($T_d$).

Recent studies have used surface, radiosonde, and satellite data as well as reanalyses to examine large spatial-scale changes in water vapor concentrations. These show a general increase in water vapor over North America, although observed trends for the northeastern United States vary by study. Recent studies have used surface, radiosonde, and satellite data as well as reanalyses to examine large spatial-scale changes in water vapor concentrations. These show a general increase in water vapor over North America, although observed trends for the northeastern United States vary by study (Ross and Elliott 1996; Elliott and Angell 1997; Schwartzman et al. 1998; Gaffen and Ross 1999; Robinson 2000; Houghton et al. 2001; Ross and Elliott 2001; Trenberth et al. 2005; Dai 2006) (Table 1). The Mount Washington record provides a long-term water vapor record from northern New England that is unique due to its elevation (1914 m), mean annual barometric pressure (802 hPa), and exposure to predominantly free troposphere conditions; 50% of days experience advective free troposphere influence and 20% (37%) of winter (summer) days experience convective boundary layer influence (Grant et al. 2005). This paper presents the dewpoint, relative humidity, and water vapor mixing ratio records for the period 1935 through 2004.

2. Data and methods
   a. Location
   The Mount Washington Observatory (hereafter Observatory) is located in the northeastern United States atop Mount Washington (44°16’N, 71°18’W, 1914 m ASL) the highest peak of the Presidential Range, which is part of the Appalachian Mountains (Fig. 1). The rocky summit is surrounded by the White Mountain National Forest. Treeline in the Presidential Range ranges from 1100 to 1700 m and the alpine and subalpine zones together cover 2748 ha (Kimball and Weihrauch 2000). The Observatory operates a National Weather Service (NWS) “cooperative observation” station and currently transmits hourly and synoptic observations. From 1932 through 1937 the Observatory occupied a succession of wooden buildings on the southeast portion of the summit cone of Mount Washington. In August 1980 the station was moved 91 m north and 6 m up in altitude to the current location. Further details of station location are given by Grant et al. (2005).

b. Data collection
   Meteorological observations have been taken at the Observatory since 1932 and hourly, synoptic, and daily summary data have been recorded on NWS Form B-16 and its predecessors. Grant et al. (2005) presented an analysis of hourly and daily maximum and minimum temperature from 1935 to 2003. That digital dataset has been extended for this study to include hourly, synoptic, and daily summary data from 1935 to 2004. This work presents the first analysis of the four daily synoptic observations, as described below.
1) PSYCHROMETRIC OBSERVATIONS

Throughout the entire period, dry and wet bulb temperatures \((T, T_w)\) have been measured by trained observers using manual sling psychrometers containing two mercury thermometers. Thermometers are supplied by the NWS and certified to their published specifications (Wright 1995). The thermometers currently in use are manufactured by Kessler Instruments, procured from the Gray, Maine, NWS Forecast Office (J. Mansfield 2006, personal communication) and are replaced on an irregular schedule, mostly determined by breakage. These thermometers have a working range of \(-39^\circ C\) to \(43^\circ C\). The thermometers have a precision of \(\pm 0.6^\circ C\). When possible (due to limited supply) wet and dry bulb thermometers are compared side by side to minimize bias in ambient air readings. No calibration checks beyond pairing are performed on the mercury thermometers. It is assumed that the aperiodic replacement of mercury thermometers would not lead to artificial trends. Psychrometric observations, with room for human error, are taken using published methods, including maintaining a clean wet bulb wick, wetting with deionized water, ventilating at sufficient speed (observers count rotations per second to produce the correct airflow rate), working in a shaded location to avoid direct radiation, assuring the wet bulb freezes in cold conditions, and reading \(T\) and \(T_w\) at the same time (USDA 1939; USDG 1969; Wright 1995; WMO 1996).

A record of this length with no changes in methodology for atmospheric moisture measurements is unusual since most surface observation stations have substituted automated hygrometers since 1960 (Elliott 1995). The Observatory can attribute this long record with consistent techniques to the harsh winter conditions of Mount Washington, particularly rime ice accumulation. The challenging conditions have made sling psychrometers, which can be brought inside between observations, the most cost-effective and practical manner of obtaining humidity measurements.

Prior to 1939 sling psychrometer readings were taken twice daily (0700 and 1900 LST; LST = UTC − 5) as part of synoptic observations (Monahan 1933). Since 1939 four synoptic observations have been taken each day (0100, 0700, 1300, and 1900 LST). Actual observation times vary within \(\pm 0.5\) h of these nominal times. Dewpoint temperature \((T_d)\) and relative humidity were calculated at the time of observation; however, these values are treated as suspect since psychrometric calculations have changed over time. As described below, this study recalculates these data to insure consistency.

Current Observatory procedure requires \(T\) and \(T_w\) observations only if the station is not fog bound. If the station is reporting fog (visibility less than 1 km) then \(T\) is read from the meniscus of an ‘alcohol-in-glass’ minimum thermometer. Under this condition both \(T_w\) and \(T_d\) are set equal to \(T\). Visual inspection of the original records revealed that this policy was not always followed. Periods in the 1950s and 1960s contain observations where \(T = T_w\) but \(T \neq T_d\). Two possible conditions exist for these observations: 1) the sling psychrometer was used in nonfog supersaturated air, or 2) foggy conditions existed with an incorrect calculation of \(T_d\) (incorrect because the sling was not used; therefore the humidity calculations should not be applied). Due to the nature of Form B-16, we cannot definitively ascertain if fog was observed at the time of psychrometric observation, as present weather is recorded using the criteria of presence during the preceding hour. For this analysis, if \(T = T_w\) the station was assumed to be in the fog and \(T_d\) set equal to \(T\). This assumption runs the risk of possibly overestimating fog frequency.

2) PRESSURE OBSERVATIONS

Atmospheric pressure \((p)\) readings have been taken by mercury barometer for the majority of the data record. From the start of observations, 18 November 1932, until 15 March 1945, readings were taken from a standard Weather Bureau Fortin-type mercury barometer. During a one-year period, 15 March 1945–31
March 1946, pressure was reported after having been adjusted using Correction Curve No. 1 (Falconer 1947). As described by Falconer, this model allows free-air pressure at the same height as the Observatory to be approximated by correcting the observed pressure for a “mountain effect” lowering of pressure due to the Bernoulli effect and a “building effect” change in pressure due to wind impact on the building. From 1 April 1946 to 20 July 2004 pressure readings were automatically corrected by attachment of a Bowen-type barometer to the total pressure line of the Observatory’s Pitot tube anemometer (Falconer 1947). Since 20 July 2004 pressure has been read from a Coastal Environmental System Digital Precision Barometer, also attached to the total pressure line of the Pitot tube. Pressure readings are taken at the same synoptic times as above. A NWS representative from Gray, Maine, performs annual barometer calibration checks certifying that all station barometers are reading to within 0.015 in. of mercury of a portable standard (J. Mansfield 2006, personal communication). The digital barometer is exchanged for a freshly calibrated unit during these annual checks and a standard correction is determined for the Bowen barometer.

c. Quality control

As is standard procedure at surface weather stations, the Observatory maintains a daily quality check before producing the final daily summary (Wright 1995). For this study, error checking consisted of finding transcription errors from the digitization process. Temperature, wet bulb temperature, and pressure were flagged for potential transcription errors using quality checks based on Graybeal et al. (2004). Flagged values were checked against the original hand-recorded data and either corrected or, if illegible, removed. Temperature ($T, T_w$) flagging criteria included 1) boundary conditions, 2) large steps ($\Delta T > 20^\circ$C) between adjacent readings, 3) large wet bulb depression ($T - T_w > 10^\circ$C), 4) negative wet bulb depression ($T < T_w$), and 5) large discrepancies between the recorded $T_d$ and our newly calculated $T_d$. The two dewpoints compared in flag step 5 are 1) the dewpoint calculated at the actual time of observation (i.e., 0100 LST 17 June 1959) and 2) the dewpoint calculated using the methods presented in this paper. Only 84 (173) dry (wet) bulb values out of 99 350 were illegible or missing.

Pressure quality checks used boundary conditions and large changes ($\pm 12$ mb per 6 h) to flag suspect data. Flagged values were checked against the original hand-recorded data and either corrected or, if illegible, removed. In a few instances (<20) flagged pressure values were incorrect on the original sheets, but the correct values were recovered by using secondary data available on the forms. After correction, only 134 of 99 350 pressure values were illegible or missing.

Quality-controlled dry and wet bulb temperature and pressure were visually inspected for homogeneity and also subjected to a statistical multiple change point test (Lanzante 1996). This test was selected due to the lack of comparable datasets from other high-altitude stations in New England. The Lanzante test was used on two time series, one composed of seasonal averages and one composed of monthly averages; neither produced significant change points.

d. Data classes

Data were divided into seven classes: the complete dataset (all) and six subsets, fog, clear air, clear day, clear night, day, and night using the selection criteria given in Table 2. The four classes with day and night separation are available beginning in 1939 when the Observatory switched from two to four daily synoptic observations. It should be noted that the clear-air and fog classes are mutually exclusive as are the day and night classes, but data in the clear-air or fog class are not excluded from the day or night class.

e. Dewpoint, relative humidity, and mixing ratio calculations

Saturation vapor pressures for dry and moist air were calculated from $T, T_w$, and $p$ with reference to liquid water when $T_w \geq 0^\circ$C and with reference to ice when $T_w < 0^\circ$C using Eqs. (1)–(5) in Annex 4.B from the World Meteorological Organization (WMO 1996). Vapor pressure was then calculated with the WMO (1996) Annex 4.B psychrometric formula [Eq. (6)] using the same criteria for liquid water and ice. These values were then used to calculate dewpoint temperature and relative humidity according to WMO (1996) Annex 4.B and water vapor mixing ratio ($\rho$) using the definition from the American Meteorological Society’s Glossary of Meteorology (Glickman et al. 2000). In addition to the data removed in the quality control section, data
were removed where calculated vapor pressure was negative ($n = 401, 0.4\%$ of the available data). The WMO equations were examined over a series of test values, and negative vapor pressure values result at relatively large dewpoint depressions at cold temperatures. For example, using 800 mb and a constant depression of 1°C, negative vapor pressures result at temperatures lower than $-20°C$ (dry cold observations). After removal of data with negative vapor pressure, 6% of the remaining data had temperatures below $-20°C$. Although this difficulty exists with vapor pressure, possibly due to thermometer error, Vömel’s (2006) Figs. 1 and 3 show that the Buck (1981) saturation vapor pressure equation, which closely matches that of the WMO (1996) used here, does not greatly deviate from other formulas until temperatures below $-50°C$, which are not observed at Mount Washington.

The above discussion adds to the difficulties discussed by Dai (2006) in obtaining humidity observations at cold temperatures. Table 4.3 from WMO (1996) estimates an RH standard error of 4% at 20°C increasing to 27% at $-20°C$, given a wet bulb standard error of 0.5°C. Dodd (1965) estimates an error of 0.6°C in $T_d$ for his surface climatology based on sling observations. As with other dewpoint and humidity climatologies (Table 1) we use our data because they are the observations available. We present mean values along with standard deviation after Dodd (1965) and Robinson (1998).

The data were first averaged to create monthly values. All months were at least 85% complete; only 7 months had less than 90% of data. The monthly averages were then averaged into 3-month seasonal [December–February (DJF), March–May (MAM), June–August (JJA), and September–November (SON)] and annual values for each data class. Standard deviations reported are associated with the seasonal means. Trends were calculated from seasonal mean values using linear regression. Trend significance was determined by using the standard $p$ value.

### 3. Results

The following sections present means and trends for temperature, dewpoint temperature, relative humidity and fog frequency, and water vapor mixing ratio, respectively. For each parameter tabulated mean values and plots of linear trends are shown for both the complete 1935–2004 period and the shorter day/night period (1939–2004).

#### a. Temperature

Mount Washington’s 1935–2004 annual mean temperature is $-2.6°C$; all means are shown in Table 3. Clear-air classes are warmer than the corresponding classes with both clear-air and fog observations. Day
and clear-day mean temperatures are warmer than the corresponding night classes. Standard deviations for both the 1935–2004 and 1939–2004 periods ranged from 0.6°C (all annual) to 1.8°C (winter fog).

Eleven out of 15 classes of the 1935–2004 temperature record (i.e., all spring, clear-air spring, fog annual, etc.), shown in Fig. 2, show positive changes. The dominant feature is a strong spring warming; however, only clear-air spring temperature, as seen in Fig. 3, has increased significantly.

The annual (+0.3°C) and seasonal changes (all winter: +0.5°C, all spring: +1.0°C, all summer: −0.1°C, all fall: −0.1°C) for the 70-yr period are generally consistent with those of Grant et al. (2005), who analyzed one fewer year of data (1935–2003) derived from daily maximum and minimum temperatures. Grant et al. (2005) found winter (spring) increase to be 0.71°C (0.80°C). Inspection of the updated dataset showed winter (spring) 2002–03 and 2003–04 to be relatively cold (warm), leading to the respective changes. This highlights the sensitivity of a trend to the data window as explored by Grant et al. (2005).

Similar to the 1935–2004 trends, 1939–2004 seasonal temperature trends, shown in Fig. 4, are positive on an annual basis, mostly driven by increases in winter and

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**Fig. 2.** Annual and seasonal temperature decadal trends for 1935–2004: (a) all, (b) fog, and (c) clear-air classes. Gray shading indicates 5% significance.

**Fig. 3.** The 1935–2004 clear-air (dashed line) and fog (dotted line) classes spring temperatures and their linear regressions lines [top (clear air) and bottom (fog)].

**Fig. 4.** Annual and seasonal temperature decadal trends for 1939–2004: (a) all, (b) fog, (c) clear-air, (d) clear-day, (e) clear-night, (f) day, and (g) night classes. Gray shading indicates 5% significance.
spring. During the 1939–2004 period, all spring temperature had a relatively large increasing trend that appears to be associated mainly with clear-air conditions. Summer, winter, and fall for the seven classes show mixed and statistically insignificant changes. For all four seasons the clear-day and day classes tend to show either smaller temperature increases or larger decreases than clear-night and night classes, which result in a smaller diurnal temperature range, similar to Grant et al. (2005).

b. Dewpoint temperature

Dewpoint trends over the 70-yr period are significantly decreasing in annual, winter, summer, and fall clear-air classes; while the all class shows an insignificant decrease for the seasons. Trends for all, fog, and clear-air classes are illustrated in Fig. 5. Mean values are shown in Table 3; standard deviation values ranged from 0.7°C (all annual) to 2.0°C (winter clear air). However, these simple linear trends do not capture the relative maximum in the 1950s and minimum in the early 1980s seen in the clear-air subset time series (Fig. 6). These changes in slope within the study period are also seen in the other humidity variables, but we restrict the discussion here to linear trends for the entire period and address the shorter length variation below. The 1939–2004 all and clear-air trends are similar to 1935–2004, while the day and night classes, shown in Fig. 7, show decreasing trends. The 1939–2004 standard deviation values ranged from 0.7°C (all annual) to 2.2°C (fall clear day); means are listed in Table 3. Winter and fall show the largest decreases in all subsets. Spring, the only season to see significant warming (Fig. 4), is the only season to not show any significant decrease in dewpoint. Mount Washington 1935–2004 mean seasonal dewpoint temperatures (Table 3) are close to monthly averages for the years 1950–1960 reported by Dodd (1965) in his Fig. 14: (all approximate) January: −15°C, March and May mean: −8°C, July: 7°C, and September and October mean: −3°C.

c. Relative humidity and fog frequency

Relative humidity (RH) has decreased annually and in all seasons with the largest all class decreases in winter and spring; values are shown in Fig. 8. These decreasing trends are consistent with the drying implied with the observed $T_d$ decrease and $T$ increase. Clear-air relative humidity for all four seasons has decreased at a rate more than twice as much as all data. Mean frequencies of fog for the 70-yr period are annual: 57%, winter: 65%, spring: 56%, summer: 51%, and fall: 58%, with standard deviations of 4% (annual) to 7% (summer). Mount Washington has seen an increase in fog frequency during the study period (Fig. 9). The negative trend in clear-air RH (Fig. 8b) is larger than the positive trend of fog frequency (Fig. 9), and the difference is largest in winter and spring, which have the largest all RH negative trends. As a check, predicted all RH trends were calculated for each season by taking the mean of the clear-air RH trend and fog RH trend (0) weighted by the mean fog and clear-air frequencies. These predicted all trends deviated from all trends (Fig. 8a) according to the sign of the fog frequency trends. For example, the predicted winter all trend of $-0.5\,\text{decade}^{-1}$ is smaller than the actual trend of $-0.4\,\text{decade}^{-1}$ due to the increase in fog frequency. Although RH has a relative maximum in the 1950s (Fig. 10) there is no increase at the end of the record similar
to that in $T_d$. There is little difference between day and night trends (Fig. 11). All decreases are significant except summer and fall day. During this time period there has been an annual, summer, and fall increase in frequency of fog, as plotted in Fig. 9.

Average clear-air relative humidity values show seasonal variation (Table 3) and are consistent with other midlatitude climatologies (Dai 2006; Fig. 4). These seasonal variations are dampened in the all class due to the frequency of fog. Standard deviation of the mean RH values range from 1% (all annual) to 6% (winter clear air) for the 1935–2004 period and 1% (summer all) to 7% (winter clear air) for the 1939–2004 period.

**d. Mixing ratio**

Similar to the dewpoint trends, annual mixing ratio for 1935–2004 (shown in Fig. 12) has decreased significantly in clear-air classes. Standard deviations of the mean values (Table 3) range from 0.2 (all annual) to 0.5 g kg$^{-1}$ (clear-air summer). The fog class shows small increases and the largest all trend was a fall decrease. The time series of fall all data and the clear-air subset, plotted in Fig. 13, are again similar to $T_d$ in exhibiting a maximum value in the 1950s and a minimum in the 1970s. With selection for day and night, shown in Fig. 14, mixing ratio shows a larger drying trend in both clear-day and day classes than clear-night and night classes. The significant trends in mixing ratio vary from $-0.03$ (clear-air winter) to $-0.2$ g kg$^{-1}$ decade$^{-1}$ (clear-day summer). It should be noted that the winter trends, although smaller, represent a similar percent change (i.e., clear-air winter and clear-day summer are both $-2\%$ decade$^{-1}$) relative to the mean. Standard deviations of the 1939–2004 mean values (Table 3) range from 0.2 (all annual) to 0.6 g kg$^{-1}$ (clear-day summer).
4. Discussion

Prior studies of tropospheric water vapor (Ross and Elliott 1996; Elliott and Angell 1997; Schwartzman et al. 1998; Gaffen and Ross 1999; Schwartzman et al. 1998; Gaffen and Ross 1999; Robinson 2000; Houghton et al. 2001; Ross and Elliott 2001; Trenberth et al. 2005; Dai 2006) considered a mix of units, data sources, and temporal and spatial scales and yielded conflicting results for northeastern New England (Table 1). Interpretation of figures covering this geographic region show six studies with increasing trends and four with mixed trends, with the majority of positive trends based on radiosonde data. Generally, studies considering shorter and more recent time periods (1970s to 1990s) show increases in water vapor and those with longer time periods (<1960 to 1990s) show mixed results. Dai (2006) convincingly argues the later humidity...
increase is attributable to the large increase in temperature over this shorter period. Mount Washington dew-point and mixing ratio, although decreasing over the full 70-yr period, appear to have seen a maximum in the 1950s and a minimum in the late 1970s or early 1980s followed by a return to increasing values (Figs. 6 and 13). This later increase agrees with the studies of shorter length and perhaps reflects the seemingly larger temperature increase in the second half of the Observatory’s record.

Four additional potential explanations for the changes in humidity at Mount Washington over the 70-yr period are 1) changes in the frequencies of airmass types affecting the station (changes in dry air types), 2) constant frequency of air masses with modification at their source regions, 3) constant frequencies of air masses with modification during transport, or 4) a combination of all three. In addition, any synoptic change is likely to produce mesoscale and orographic effects, potentially modifying water vapor concentrations further.

Airmass frequency can be determined by defining synoptic classes based on either interpretation of source regions on weather maps or by defining standard meteorological characteristics and then applying a classification scheme over time (Kalkstein et al. 1996; Keim et al. 2005). Kalkstein et al. (1998) used the “Spatial Synoptic Classification” (SSC), an automated classification system, to broadly show that winter dry polar (DP), dry moderate (DM), and moist polar classes have increased, at the expense of transitional air masses, across the United States. This suggests that data from a redeveloped SSC (Sheridan 2002) (available online at http://sheridan.geog.kent.edu/ssc.html) could show regional airmass-type frequency changes consistent with Mount Washington’s trends in dewpoint and mixing ratio. Because SSC winter DP air masses are usually associated with clear, dry conditions, we attempt to use this data to investigate the dewpoint trends in our winter clear-air class (Fig. 6).

Provided air masses are not modified enough to appear as different airmass types, explanations 2 and 3 (modification of air mass) would be indistinguishable in the record from Mount Washington. Kalkstein et al. (1998) identified characteristic trends within air masses. In particular, and of interest, they observed a widespread dewpoint decrease in winter DP air masses. Our winter clear-air value of $0.3^\circ C$ decade$^{-1}$ (Fig. 7) is in reasonable agreement with that of Kalkstein et al. (1998) for northern New England ($0.4^\circ C$ decade$^{-1}$). Kalkstein et al. (1998) found, similar to the change observed on Mount Washington, that most of the dewpoint decrease occurred before the mid-1970s, and noted that this decrease coincides with a period of increased meridional flow. Using 1977 as a starting point for the recent period of zonal flow (Trenberth 1990) the Observatory record shows increasing dewpoint temperature (Fig. 6). This within-airmass dewpoint increase suggests modification of the DP airmass type prior to advection to Mount Washington.

Winter DP frequency in New England increases through the late 1970s and then decreases to the end of the record; individual stations are shown in Fig. 15 with linear trends summarized in Fig. 16. Most stations show a decrease in winter DP frequency of $-4\%$ decade$^{-1}$,

![Graph showing mixing ratio decadal trends for 1939–2004](image_url)
with the southernmost station, Hartford, Connecticut, showing the largest decrease. In each case DP appears replaced by either (or both) a warmer or moister air mass. Although this apparent regional decrease in DP airmass frequency provides a plausible explanation for the Observatory’s recent increase in water vapor, the clear-air class frequency actually increases (4% decade\(^{-1}\)) at the end of the record (Fig. 17), contradicting our claim that winter clear air provides a direct local proxy for the DP class. It is possible that the winter clear-air class matches both the SSC DM and dry polar classes, which, when considered together, do not show the same decreasing trend as DP alone. This shift from DP to DM would provide a source of warmer air potentially less likely to be cooled to saturation by orographic uplift.

5. Conclusions

We present a 70-yr humidity climatology and seasonal trends for the summit of Mount Washington with
subsets to allow analysis of diurnal and fog/clear-air variability. Annual synoptic temperature has increased 0.3°C from 1935 to 2004 with a significant increase of 0.2°C decade⁻¹ in the spring clear-air class. Mount Washington shows statistically significant decreases in clear-air dewpoint temperatures in all seasons except spring. Mixing ratio has decreased significantly in fall (−0.05 g kg⁻¹ decade⁻¹) for 1939–2004 all data. Similar to dewpoint, mixing ratio has larger decreases in clear-air subsets. Unlike dewpoint, mixing ratio clear-day trends are larger than clear-night trends. The summit shows an increase in the frequency occurrence of fog in summer, fall, and annually. The decreasing trend in humidity appears restricted to the earlier portions of the record (pre-1970s) with dewpoint and mixing ratio increasing at the end of the period. The water vapor record from Mount Washington shows potential indicators of changes in airmass frequency, characteristic modification within air masses, and, more recently, a potential response to increase in temperature.

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