A Data Exploration of Visibility at Mount Washington Observatory (1943 – 2020), KMWN: Key Findings

Mount Washington Observatory

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Outline:

1. Abstract

The main goals of the Data Exploration of Visibility Project were to 1) explore the availability and quality of visibility data on Mount Washington and 2) conduct an initial analysis to determine what, if any trends were apparent since 1943. All available visibility data were extracted from the Mount Washington Observatory's (MWO) summit database to determine what might be available for analysis. The data were then compiled into groupings such as seasonal averages, and counts of 100 miles or greater observations, and plotted over time. Overall, a general increase in visibility has been reported since continuous visibility records started at MWO.

2. Introduction:

a. Objectives

This paper presents and explains the exploration of manual, hourly prevailing visibility data reported from the summit of Mount Washington, NH from 1943 to the present for the existence of trends or anomalies. Temporal patterns in visibility are reported as the baseline for future studies on the relationship between visibility and air quality. A summary of the datasets used, methods, and findings will be shared with external researchers for application to other historic datasets.

b. Motivation and History

MWO meteorologists have observed and reported prevailing surface visibility nearly every hour since 1943 with few gaps. MWO's visibility data were largely unavailable to the public and have not undergone recent quality control and long-term analyses. Specifically, an analysis of prevailing visibility was of interest to determine if any long-term trends or anomalies exist.

Motivation for the investigation was initially born from public inquiry about whether MWO data showed a difference in reported prevailing visibility with a reduction in air traffic and other industry due to the COVID-19 Pandemic. Often referred to as the "tailpipe of America," prevailing west to east winds transport aerosols and particulate pollution from the Ohio River Valley and further west to New England causing reduced visibility and air quality. As the highest point in the Northeast with a treeless summit, Mount Washington's position allows for an unobstructed view in all directions and maximum clear-sky visibility of 130 miles with peaks as distant as Mount Marcy in New York State visible to the naked eye.

Unpublished analysis of historical visibility data at Blue Hill Observatory, located roughly 10 miles southwest of Boston, Massachusetts, indicates a notable increase at 7 am daily visibility reports since 1965 (Iacono 2020). With over 70 years of hourly visibility data, a time-series analysis of MWO's long-term visibility will help researchers in their understanding of how and if regional visibility has changed over time.

c. External Relevance

As a result of the Visibility Data Exploration, the MWO's long-term, high altitude visibility dataset will be available to air quality specialists, meteorologists, and the public for further studies on air quality, weather, climate, and environmental health.

3. Datasets and Methods

The datasets used in this project came from MWO's internal data records as follows:

- Lowest Hourly Visibility from B-16 observation database (December 1942[1] – 2020)
- Prevailing Hourly Visibility from the raw manual database (2009 – 2020)

According to the Federal Meteorological Handbook No. 1, prevailing visibility is defined as the furthest surface visibility observed during the observation time, that equals or exceeds 180 degrees of the horizon circle around the point of observation. Prevailing visibility is recorded at each of the 24-hourly observations, every day of the year. Before 2008-2009, prevailing visibility was recorded solely on the National Weather Service's Surface Weather Observations METAR/SPECI MF1M-10C form and has yet to be digitized. Beginning in 2009, hourly prevailing visibility has been recorded solely in the digital database.

In conjunction with prevailing visibility, the lowest visibility was also recorded throughout most of MWO's station history. The lowest visibility is defined in MWO's Station Manual and accepted by the National Weather Service as the lowest prevailing visibility reported in the last two observations. For example: if the current observation time is 1756 EST and the prevailing visibility is 50 miles, but the previous observation reported prevailing visibility of 1/16th of a mile, then the visibility reported on the B-16 Form[2] in Column 8[3] for the current observation would be 1/16th of a mile.

This exploration project used the Lowest Visibility dataset to obtain daily, monthly, seasonal, and annual averages of the lowest visibility from the observation location (observation deck atop Sherman Adams Building) located at the summit of Mount Washington, which may be referred to as KMWN[4]. Before 2008/2009, the lowest visibility data were recorded on a daily paper form (B-16). In the late 2000s to early 2010s the lowest visibility data were transcribed into the digital database by interns and observers. Considering that the data were transcribed by various individuals, the possibility of transcription errors exists. Also, due to slight changes in procedure and observing/training aids (i.e., visibility charts defining peaks and distances), some visibility values over the current maximum of 130 miles were historically recorded, and are outliers. It is hypothesized that past observers estimated the visibility beyond the furthest markers due to sharp relief on clear days. In surface observation manuals as early as 1949 it states "In estimating the visibility when the farthest object is at a comparatively short distance, note the sharpness with which the object stands out. Sharp outlines in relief, with little or no blurring of

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[1] Data from December of 1942 is used to analyze seasonal averages since meteorological winter is December – February although the scope of this project focuses on the years of 1943-2020.

[2] WS B-16 form is a National Weather Service daily observation form used for hourly surface observations each observing day at MWO.

[3] Column 8 is the column on the B-16 form where lowest visibility is recorded.

[4] KMWN is the ICAO code given to the Mount Washington Observatory, which is a four-letter station identifier. All stations in the lower 48 start with "K".

color, indicate that the visibility is much greater than the distance of the reference object. On the other hand, blurred or indistinct objects indicate the presence of haze or other phenomena that has reduced the visibility to not less than the distance of the objects." It may be that observers at the time spotted the farthest markers having sharp relief, and estimated the distance seen beyond. Due to the curvature of the earth, other hills and mountains, and the growth of vegetation, the current standard for reporting maximum visibility is 130 miles. A map of common markers Observers have used can be seen in Figure 1 below.

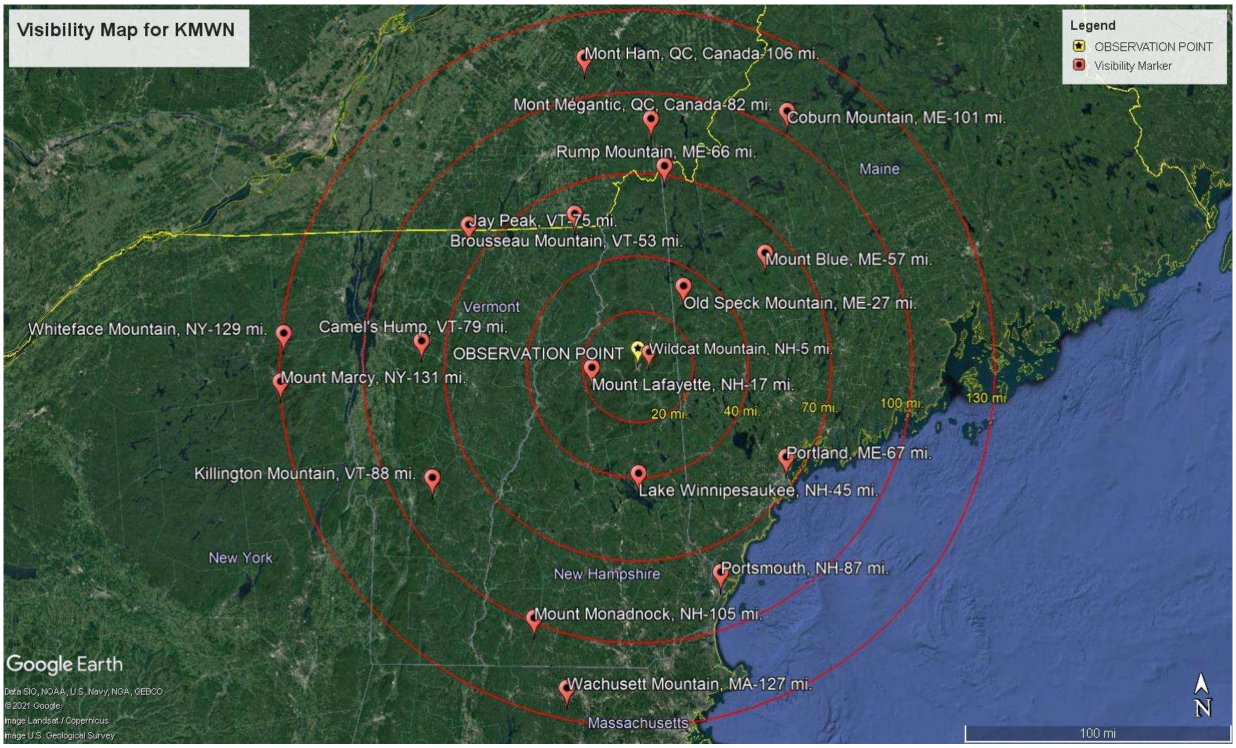

Figure 1: Map of concentric circles around KMWN with visibility markers indicated. Inner most circle is 20 miles, while the outer most circle is 130 miles.

Using monthly averages, four seasonal averages were calculated and graphed against the annual average for each year. The four seasonal averages each consist of 3 months and are as follows; December, January, February (DJF); March, April, May (MAM); June, July, August (JJA); and September, October, November (SON). The monthly averages for Prevailing Visibility were also calculated to be used to obtain seasonal averages. Note: data are raw.

4. Key Findings and Charts

There appears to be an increase in lowest visibility, subtly beginning in the 1950s and then increasing at a higher rate post-2000 (Figure 2). June, July, and August (JJA) are generally lower than the other monthly periods. There also appears to be an overall increasing trend in visibility.

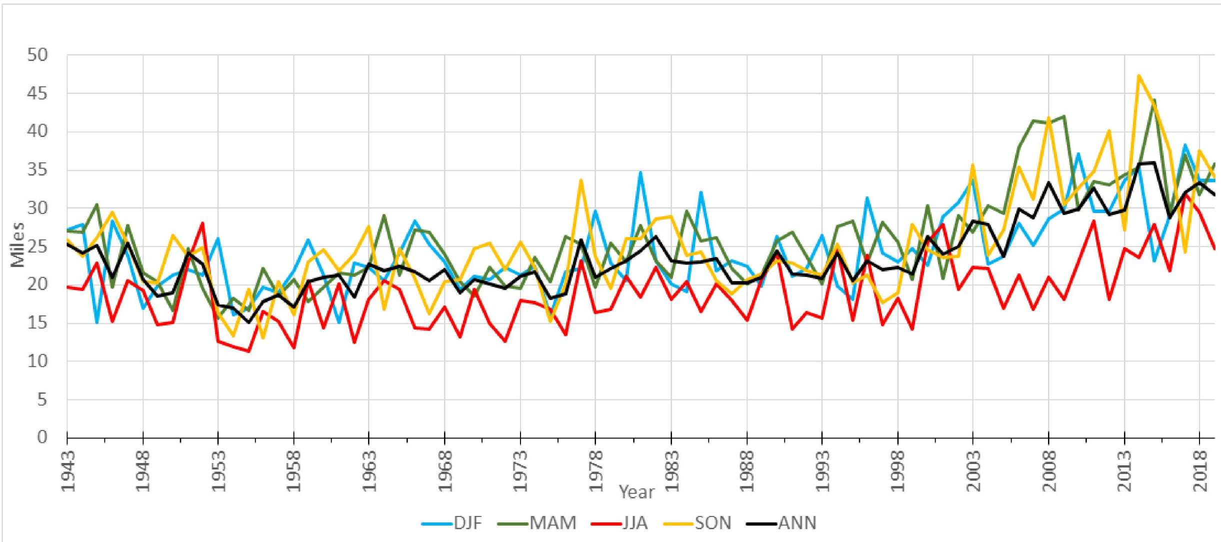

Figure 2: Seasonal average of lowest visibility (miles) at KMWN (December, 1942 through November, 2020)

Prevailing hourly visibility that is available digitally since December of 2008 appears to show that the JJA seasonal average through the 11 years is generally lower than the other seasons (Figure 3). This seems to be similar to the long-term analysis of the lowest hourly visibility since December of 1942. Public interest in whether average visibility was found to be increasing due to the slowdown of various industries due to the COVID-19 pandemic in 2020 does not appear to be easily discernible in this analysis. Overall, the annual average visibility does not appear to be increasing or decreasing during the December of 2008-2020 timeframe, averaging between approximately 35-40 miles. These data show little change over the period. It should be noted that this dataset was developed using prevailing visibility, which differs from the lowest visibility.

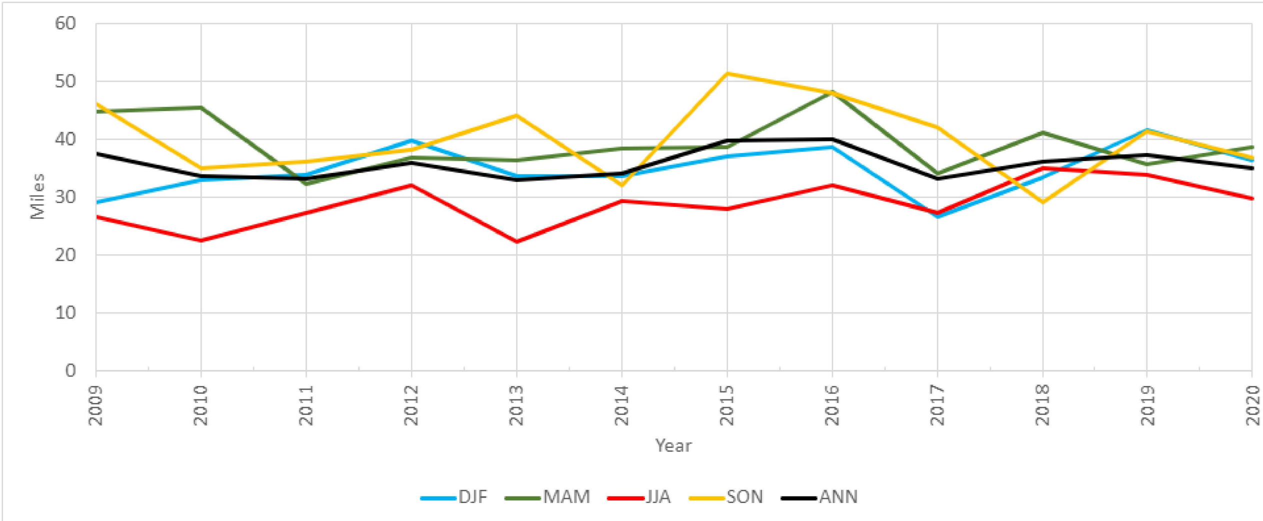

Figure 3: Seasonal averages of prevailing visibility (miles) at KMWN (December, 2008 through November, 2020)

Since the original intent of exploring MWO's visibility data were to examine prevailing visibility, it is important to establish confidence in the lowest visibility dataset as the lowest visibility dataset spans a larger time frame through the MWO's history. This comparison is necessary to show the data of both prevailing and lowest visibility follows similar trends, and how the lowest visibility can be confidently used as a valid proxy when discussing prevailing visibility trends. Looking at both visibility datasets for the period where they overlapped (2009-2020), prevailing visibility annual averages were approximately 4 miles greater than lowest visibility annual averages (Figure 4).

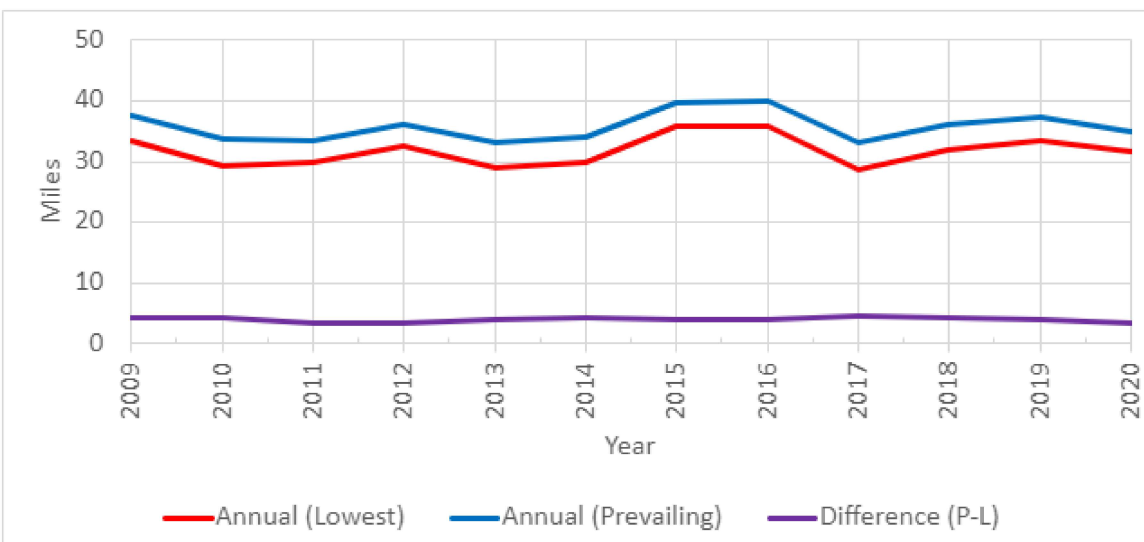

Figure 4: Annual averages of Lowest and Prevailing Visibility at KMWN (2009 through 2020)

The box and whisker plot shows a basic statistical analysis of the number of 100 miles or greater lowest visibility observations for each decade from 1940 through 2020 (Figure 5). Note that data were either missing or not recorded for the year 1940, hence the "1940" decade shows a minimum of zero observations with visibility greater than or equal to 100 miles. It should also be noted that the years 1941-1943 had some missing days with reported data being slightly inconsistent. The "2000"'s decade had the most variability for individual years. In comparison, the "1960"'s and "1970"'s had little variability year to year. A final observation is that the "1960"'s and "1980"'s contained statistical outliers. For example, in the year 1983, 345 100 mile or greater lowest visibility observations were recorded, with the next highest in that decade being 155 in the year 1986.

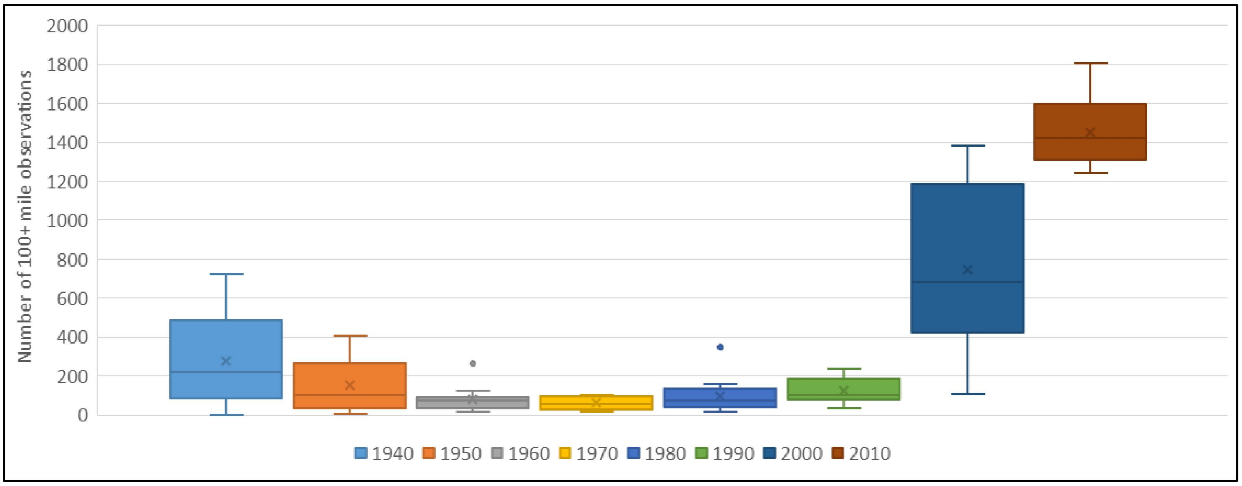

Figure 5: Box and Whisker plot of the number of 100 miles or greater lowest visibility observations at KMWN (1940 through 2020), note that each series is one decade (i.e., 1940 = 1940 through 1949).

5. Parameters for Further Exploration and Questions

Some possibilities of parameters for further exploration include investigating relative humidity, particulate concentrations, as well as pressure, wind direction, and speed. Additional analysis could include an examination of observation visibility records with a <5/8th mile visibility, the criteria for fog, or observations where present weather occurred (such as precipitation) to see if any trends exist when the relative humidity is less than 99%. Wind direction and speed could be compared with other atmospheric particulate concentrations, natural and anthropogenic, over specified periods of interest. Southwest winds are thought to transport particulate matter from the Ohio River Valley, which could potentially affect visibility on Mount Washington. Examining the above-mentioned parameters may also indicate why JJA appears to be the season with the lowest visibility. The differences between daytime and nighttime visibility data may potentially highlight any trends or differences between the way visibility behaves once the sun sets.

Although study indicates that lowest visibility is an adequate dataset to analyze visibility trends, there is a future opportunity to digitize all of the prevailing visibility records prior to 2008. Since there are questions as to why there appears to be a rise in variability and a rise in average visibility around the year 2000 through present day, prevailing visibility should be compared with lowest visibility to be able to extend Figure 3 and allow for further statistical analysis. Finally, with the creation of a visibility metadata file, future metadata related to visibility measurements should be added to this file moving forward.

6. Acknowledgements

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7. References

Iacono, M.J. (2020). [Blue Hill Observatory Seasonal Visibility, 1965-2019]. Unpublished raw data.