Summit Wind Trends and Recorded Instrumentation Values 1941-2023

Maya A. Hartley

ABSTRACT

The research done for this project is a continuation of an analysis of wind trends atop the summit of Mount Washington first investigated by the Appalachian Mountain Club and Mount Washington Observatory. This aforementioned study concluded that there were no notable wind trends atop the Mount Washington summit, however, this project aims to investigate summit winds more meticulously with a primary focus on the frequency of summit Big Wind events. Wind direction and velocity data was analyzed from 1941-1980, and then separately analyzed from 1981-2023, after the anemometer used to record summit winds was moved 1/10th of a mile across the summit, and 25' higher from the previous location. Results from this research showed that summit infrastructure has a significant impact on the recorded wind velocities and direction. Records show that the average annual frequency of 100+ mph wind events at the new location of the anemometer is 2.4 times greater than that of the previous location. There were also significant differences in recorded wind direction between the two locations, with the new location receiving ~22% more NW winds than the previous location. Despite these discrepancies, analysis of winds from 1981-2023 does show a significant decline in the frequency of annual 100+ mph events, which could have a major impact on alpine biology. Revealing this downward trend can also help further our understanding of regional atmospheric dynamics in the context of global climate change.

INTRODUCTION

The Mount Washington Observatory (MWObs) has been in operation since 1932 and has over 91 years of recorded data on wind speed and wind direction atop the summit. Just two years after the MWObs's opening, the highest wind speed on Earth observed by man was recorded there at 231 mph on April 23, 1934. To this day, the summit of Mt Washington is known for experiencing some of the worst weather on the planet, and the analysis of wind trends atop this summit is crucial in bettering our understanding of changing atmospheric dynamics, as well as the biological health of the region's alpine zone. With the development and demolition of man-made structures on the mountain paired with the location changes of the recording instruments, however, there is some inconsistency in the conditions of which the winds are being measured. This project is an analysis of wind records on the summit of Mt Washington from 1941-2023, with a primary focus on the frequency of 'Big Wind events', which have been defined as events in which winds are sustained at 100 mph or greater. In this particular analysis, sustained winds are considered to be the averaged wind speeds over a minute time span, averaged over an entire hour. In past analyses of our records, trends were determined by analyzing the wind data from 1940-2018, however key discrepancies have often been ignored or understated in past reports. Thus, it is important to not simply analyze what the raw numbers are showing, rather, the context in which data points were recorded.

METHODS

1) *Dividing the data*

As most records of exactly when summit construction projects began and were completed are nonexistent, data was analyzed between two periods, with each having little to no major infrastructure changes within that said period. First from 1941-1980, and then from 1981-2023. None of this data was scaled or altered in any way. The data was filtered to count the number of days per year in which hourly sustained winds exceeded 100 mph. Although it is known that several factors could have affected the trends observed, there was no correction done to compensate for these possible errors, as more research needs to be done on the specifics of possible influences on observatory data.

2) *The Case Against Homogenization*

In analyzing any data set to discern possible trends, it is crucial that all data being compared is standardized. With the case of the wind records from the Mt. Washington Observatory, all data would need to be physically homogenized, as there have been physical changes in the conditions at which data was collected. This would require a control dataset that stretches back to the beginning of our desired period (in this instance, 1941) until present day. Hypothetically, the data would be divided into periods of consistency; each time a new summit structure was erected/demolished and each time the anemometers moved locations, there should be a compartmentalization of data from the starting point of one change to another. Each of these finely divided sets would then be compared to the control, scaled, and then properly homogenized as 1:1, data set:control data. For multiple reasons however, this is impossible. There is a severe lack of data on when certain structures were built or demolished, just as little data on the exact dates of anemometer location changes, and, most notably, there is no unchanging wind record of any sort dating from 1941 to present day to act as a control set. Homogenization of this data, and in turn, the simple analyses of trends stretching back from 1941 until present day appears to be impossible. This being said, properly analyzing the data to discern any possible changes in summit wind dynamics was accomplished by separating the data sets based on consistent siting, and then interpreting the records with the context that is available.

3) Structural changes the summit

Summit infrastructure changes frequently and drastically. With each change, the wind field across the summit is altered, thus affecting the directions at which winds are being received, the speed and intensity of winds at different heights, and the interactions the winds have with one another. In this analysis, there is a primary focus on the influence of the Yankee Building specifically on the summit wind field.

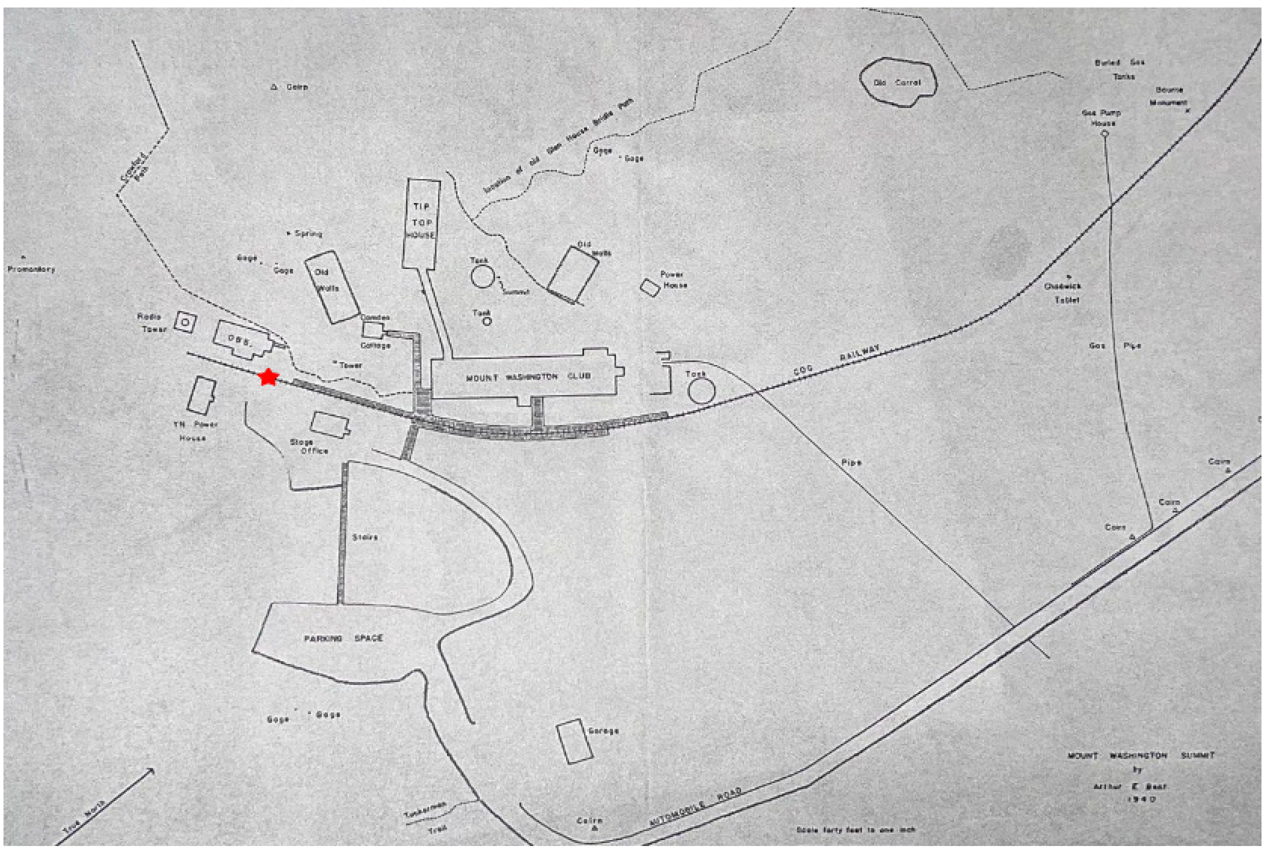

Figure 1. Mount Washington Summit, 1935. Source: A.E. Bent, *Map of Mt. Washington Summit*

Figure 1 depicts the summit's infrastructure in 1935, before the construction of the Yankee Building, when the average number of Big Wind events per year was 92. Eliminating the outlier, (1936, which had 268 recorded sustained winds over 100 mph) the average number of Big Wind events during this period was 57.6 per year. At this time the anemometer, which is represented by the red star in figure 1, was at ~6292', atop the detached tower of the old observatory building.

In 1941, the Yankee Building was constructed, and the anemometer, again represented by the red star in figure 2, was moved to the attached tower of the observatory building. This combination left the anemometer in the lee of the Yankee Building, which is an L-shaped building with a maximum height of 22’.

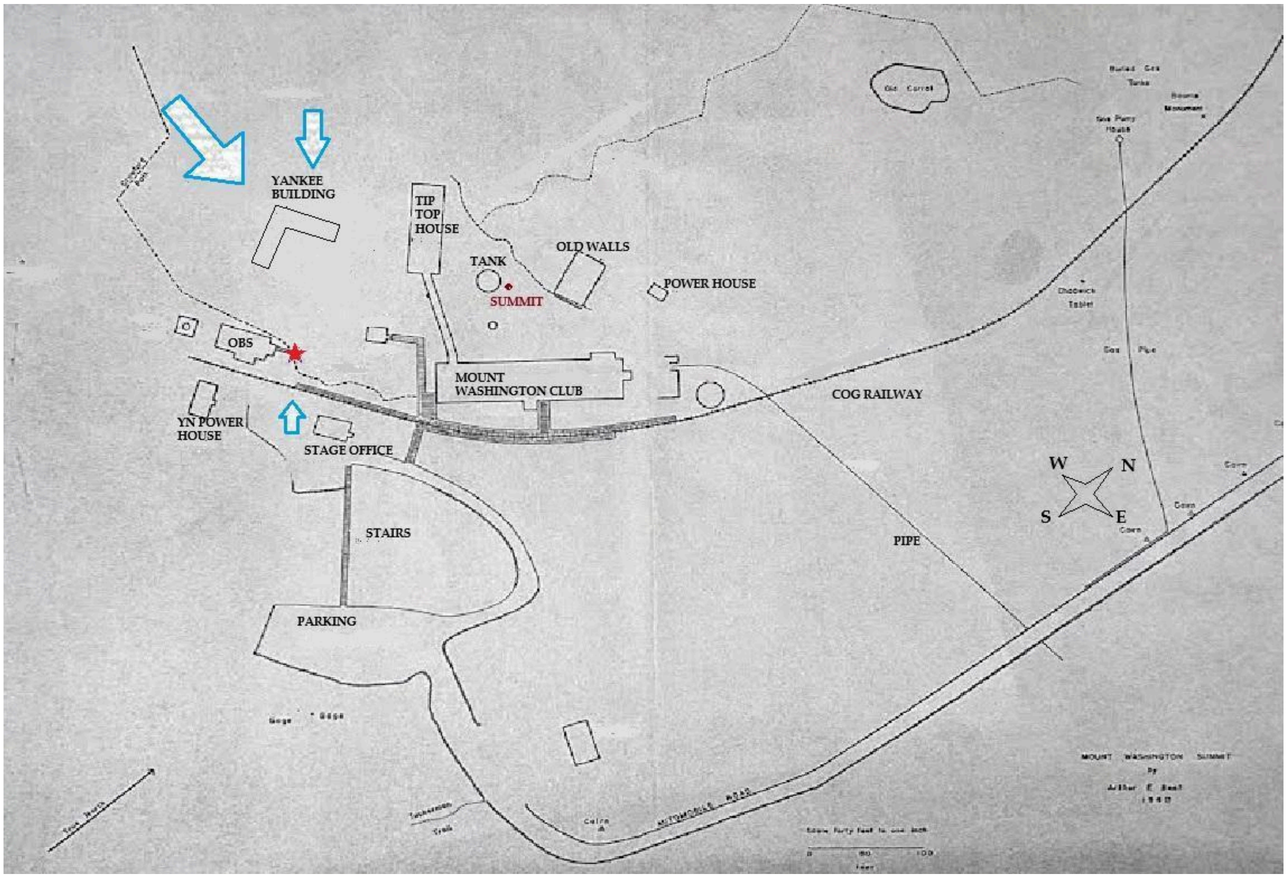

Figure 2. Mount Washington Summit, 1941. Source: A.E. Bent, *Mount Washington Summit Map, 1941*

In Figure 2, the most prevalent winds are represented by blue arrows. During this period from 1941-1980, approximately 50% of measured winds were out of the west, and about 22% out of the northwest.

In August of 1980, the construction of the Sherman Adams building was completed, and the Mount Washington Club building was completely demolished. This new building is shown in figure 3, and was a drastic change from the state of the summit in 1941.

Figure 3. Mount Washington Summit, 2018

4) Monitoring changing anemometer locations

If any analyses are to be done prior to 1941, it is important to note that the anemometers existed at three different locations between 1932 and 1941, and there is no record on the exact dates of these first location changes. The only anemometer location change that is sufficiently documented was the move from the 1941-1980 location (represented by the red star in figure 3) to the 1980-present location (represented by the yellow star). In 1980, the Sherman Adams building was completed, and the anemometer was moved approximately 1/10th of a mile to the SE of the previous location. Taking into consideration this significant distance change, the direction to which the anemometer moved, and the height difference of the anemometers, are all crucial in contextualizing the major changes we see between data from 1980 and 1981. Another important aspect to consider is the fact that the construction of the Sherman Adams building once again altered the wind field on top of the summit.

5) Monitoring wind direction

When analyzing winds it is important to account for the direction of which the winds are originating. In this particular analysis, as observational winds are recorded directionally as opposed to the specific numbered degree, a program was created to translate the cardinal direction measurements into a 360 degree range. In this instance, a recording of northerly winds was assigned an equivalent of 0 degrees, easterly winds assigned 90 degrees, northeast winds assigned 45 degrees, and so on. Once each data point was translated from its recorded cardinal direction to a specific degree, a wind rose was created, allowing for visualization of what percentage of winds were coming from which direction. For easier reading, the 0-360 degree scale was represented by the cardinal directions, with each ring of the wind rose representing the 10% threshold.

6) Data analysis

MWObs data on hourly sustained wind speed from 1941 until 2023 was analyzed for this project. Each hour for each day during this timespan has a recorded sustained wind speed, which is calculated using the average wind speed across a minute, averaged over the hour. Hours in which there was nulled data were eliminated from the analysis.

The data was divided into two periods, with the first being from 1941-1980 and the second being from 1981-2023 as in accordance with the change in anemometer locations which took place in August, 1980. A standard was then set: each hour with sustained hourly winds greater than 100 mph was considered to be a Big Wind event. The number of Big Wind events each year was then tallied, and then using Microsoft Excel, the graphs represented in Figures 4 and 5 were composed with a least linear squared regression line fit to each graph with the slope of this line noted, to better depict any possible trends that may have occurred.

In addition to the graphs, wind roses were composed through a Python script. In each of these wind roses, represented in Figures 6 and 7, the data points used were the same in which each hour in which sustained winds were >100 mph was marked as a Big Wind event. These wind roses included data points up until 07/31/2024, whereas the graphs of Figures 4 and 5 only included data up to 12/31/2023, as to ensure that there was not one year which had significantly less data points than any other year.

<u>RESULTS</u>

1) Big Wind frequencies

Our data shows there is an obvious difference between received winds from 1941-1980 and winds from 1980-2023. In the analysis of Bing Wind events from 1941-1980 (shown in Figure 4), data from 1943 was removed from the analysis, as it was a significant outlier with 79 Big Wind events recorded that year – 9.88 times the average for this period. With this outlier removed, we can see that, on average, during this period there were only an average of 6.9 Big Wind events per year.

This period also does not seem to show any significant trend in the frequency of the Big Wind events.

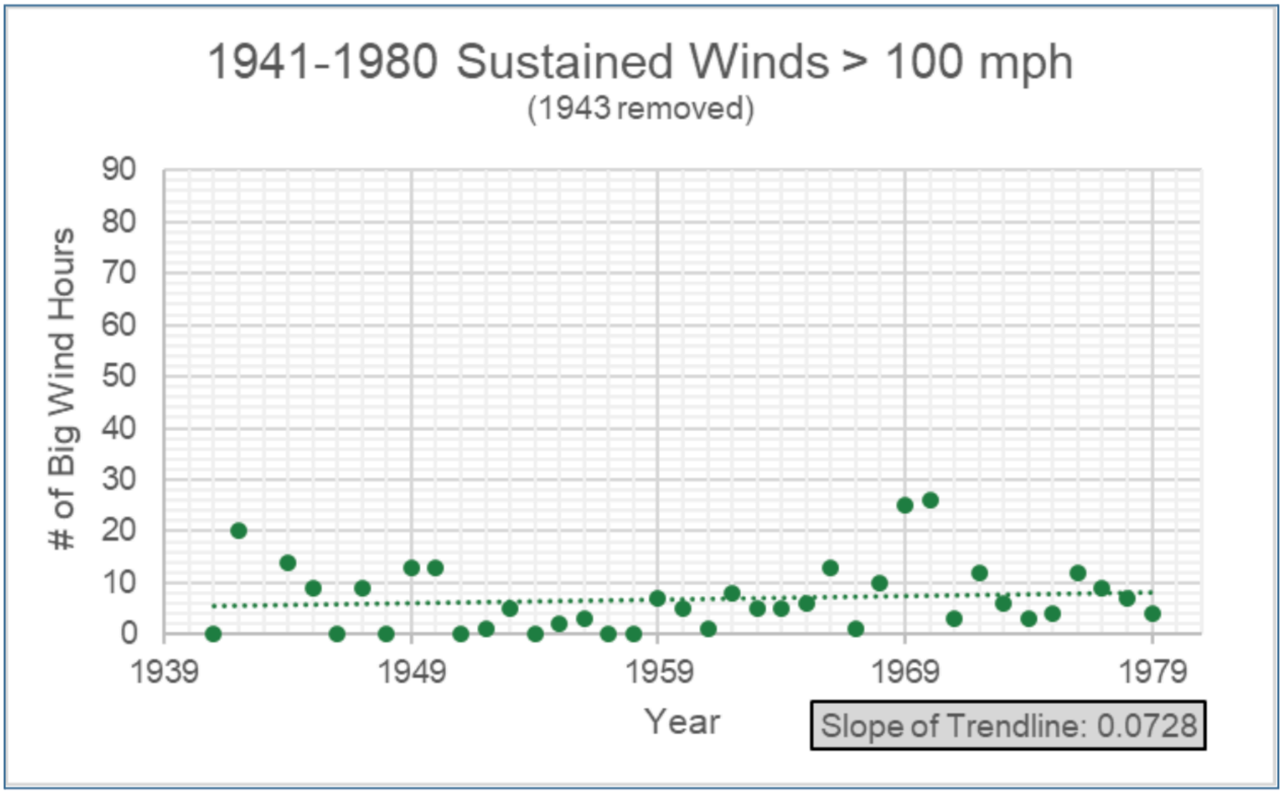

Figure 4. Number of Big Wind events from 1941-1980. Regression line and slope value are shown. 1943 was an outlier and removed.

The data from 1981-2023, after the anemometer was moved to the Sherman Adams building, reveals a different story. During this period, the average occurrence of Big Wind events was 16.6 per year, with a downward trend representing a loss of about 0.5 Big Wind events each year.

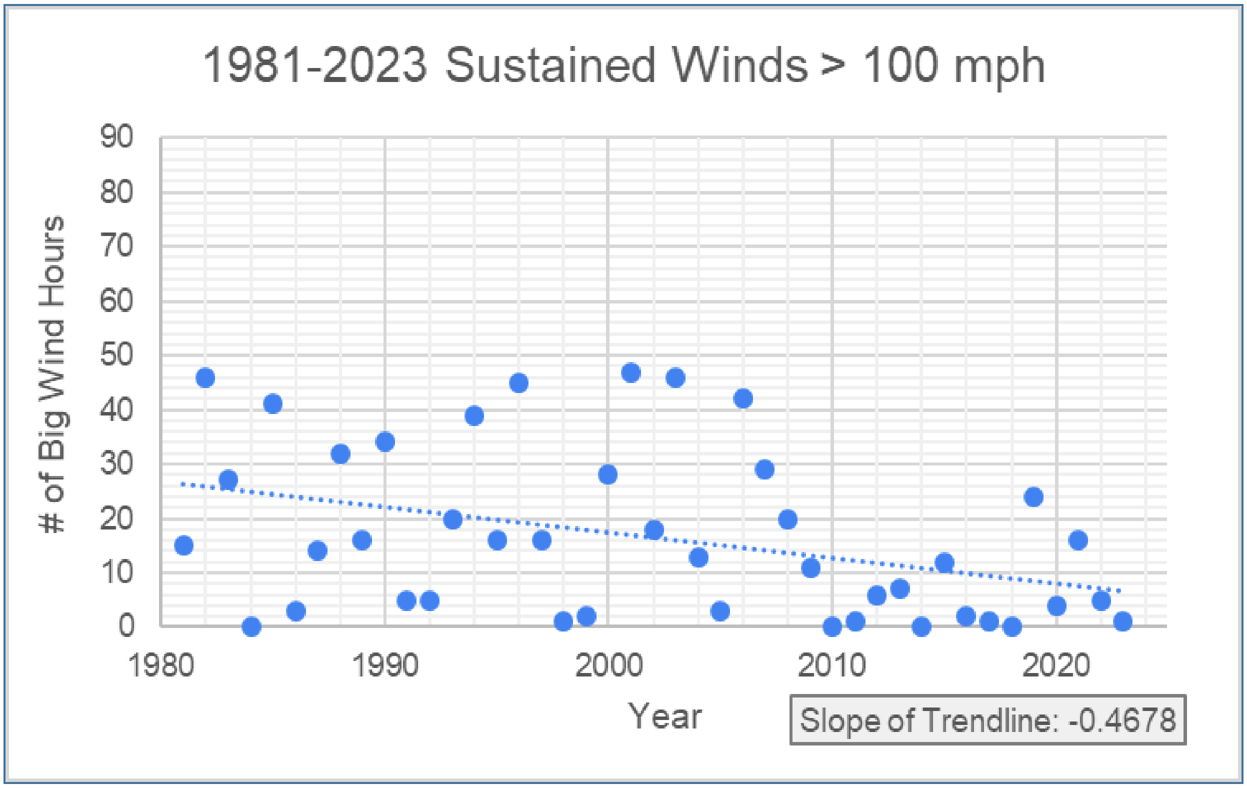

Figure 5Number of Big Wind events from 1981-2023. Regression line and slope value are shown.

It is important to note that in 2011, when the results are showing a drastic drop in Big Wind Events, flooding issues with the Pitot-11 that was used as the observatory's gold anemometer from 2011-2019 were frequently reported, as a consequence of the Pitot tube being pumped in the wrong direction in the early days of the anemometer going gold. During this time period, there was no consistent backup anemometer recording wind speeds at the same location.

2) *Wind direction*

Through this analysis of wind data, we can also see significant differences in the direction from which winds are originating between the two timeframes. Figure 6 represents the wind directions from 1941-1980 while Figure 7 shows wind directions from the date of the anemometer change on 08/01/1980 up to the day the wind rose was created, on 07/31/2024.

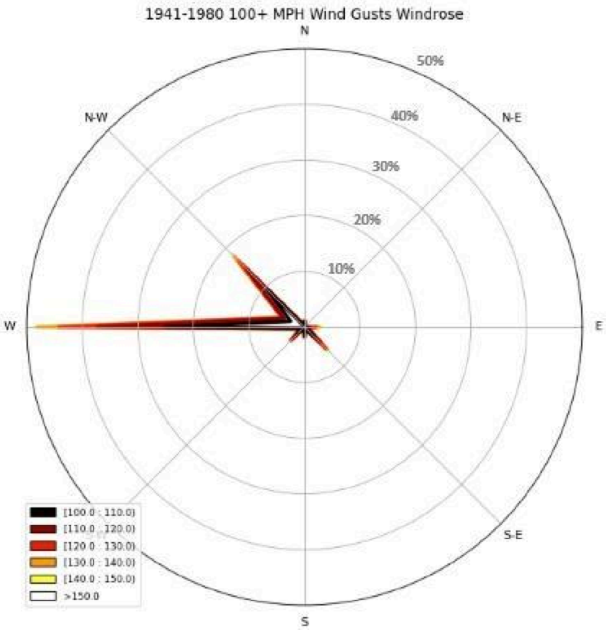

Figure 601/01/1941-07/31/1980 direction of 100+ MPH Gusts Color key represents # of 100+ MPH gusts

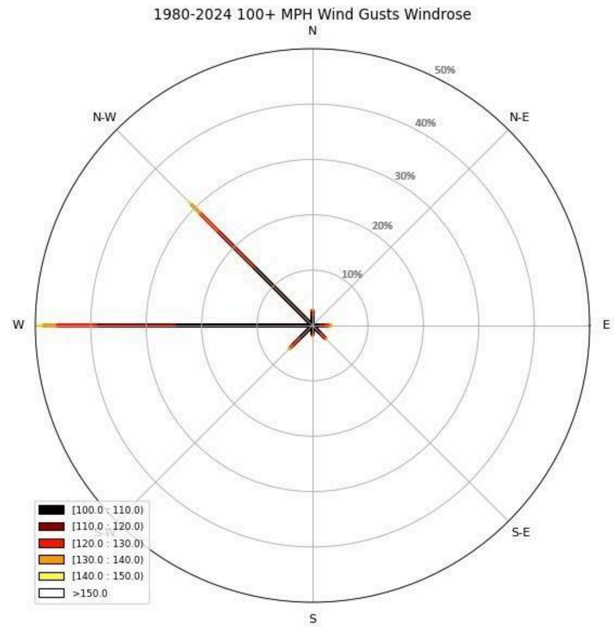

Figure 7 08/01/1980 - 07/31/2024 direction of 100+ MPH Gusts. Color key represents # of 100+ MPH gusts

It is important to note that prior to 1968, MWObs recorded their winds using 16 directions, as opposed to the 8 cardinal directions which we adopted in 1968 in order to comply with National Weather Service standards. For this reason, we see a substantial percentage of our winds in the period from 1941-1980 originating from the WNW. If winds from this direction were measured post-1968, the winds would either have been grouped into the W or the NW directions.With this being said, there is an obvious difference in the direction of the winds between the two periods. While both periods have winds prevailing from the west, it is important to note that there is a significant difference in the percentage of winds originating from the NW between these two periods. More specifically, we see about a 12% increase in NW winds after the anemometer was moved to the top of the Sherman Adams tower on August 1st 1980. Another notable distinction between these two periods, is the decrease in SE winds after this move, which was ~1/10th of a mile NE.

ANALYSIS:

The results of this research imply that the wind field atop the summit can change drastically with summit infrastructure alterations. Results also imply that the winds we measure are only a limited representation of the actual winds across the summit, completely dependent on where the anemometer lies within the wind field. From the significant decrease in Big Wind events after the construction of the Yankee building (decreasing from 58 per year before construction of Yankee building to 7 per year after construction was completed), it can be determined that the L shape of this building has a significant hindrance on the winds then at the location of the anemometer from 1941-1080. As the winds at this time primarily were out of the west (50%) and the north west (22%), and the walls of this building are near perpendicular to these prevailing winds, it is likely that this infrastructure did directly result in the significantly low frequency of Big Wind events from 1941-1980. It is also important to note the proximity of this anemometer location to the Cog Railway, which, with each moving car, contributes to wind dynamic changes multiple times a day, as the presence or lackthereof of a vehicle that size never remains consistent.

Wind direction analysis also shows differences in the dynamics at the different anemometer locations atop the summit. The major difference between the two anemometer locations is the significant increase in NW winds after the anemometer was moved to the Sherman Adams Building tower. This increase could imply one of two things: either the new location, which is ~1/10th of a mile to the SE and 25’ higher than the previous anemometer, receives more NW winds based on location alone, or, the previous anemometer location did have some sort of breakwall preventing NW winds from reaching the anemometer. A lesser, yet still notable difference in the wind direction data, is the decrease in SE winds after the move. Again, this could have multiple implications. It is likely that, with the cornered shape of the Yankee building on one side, and the Stage Office and Cog Railway on the other side of the old anemometer location, an eddy dynamic could have occurred during Big Wind events, essentially acting to ‘swing’ the winds around, leading to unnatural wind directions. Conversely, these SE winds at this old location could have been naturally occurring, and for one reason or another, there is now a hindrance from the SE direction at the new location of the anemometer.

Despite the summit wind field inconsistencies and homogenization being virtually impossible, if each period is individually analyzed without being compared to the other, it is still possible to discern trends. Although 1981-2023 is only a 42 year timespan, this is a decent record and the downward trend that we are seeing in figure 5 is still significant enough to be brought to attention, with a decline of ~0.47 less Big Wind events per year. This decline in our Big Wind hourly events could have major implications for alpine vegetation health, and further analysis of this decline can improve our understanding of atmospheric dynamic changes. It is important, however, to note the significance of the frequent malfunction of the Pitot-11, which was in operation from 2011-2019. While this could contribute to the steep drop in the number of Big Wind events during that timespan, we can not explicitly state that the anemometer is the sole reason for the decline that we see.

CONCLUSION:

Analysis of the wind data from 1941-2023 has revealed just how particular the winds are atop the summit of Mount Washington. As a result of continuous infrastructure changes, it can be concluded that the wind field, and thus, the winds we measure have changed drastically since the Observatory's beginning in 1932. Not only do the changing conditions on the summit affect the wind data that is being recorded, but the location of the anemometer also significantly affects our data as well. The differences in received winds by the anemometer at the 1941-1980 location vs the 1980-2023 location can be seen in the frequency of Big Wind events as well as in the directional analysis of the winds. While this research did reveal that received winds do appear to prevail from different directions based on location, there is still much more data combing that needs to be done to more accurately understand our directional records, primarily because of the change from using 16 directions to using 8 cardinal directions. In the future, if more intensive research is to be done on wind direction trends dating before 10/02/1967, each record of wind that does not fit in the NWS standard of the 8 cardinal directions would need to be categorized based on the appropriate standards. In order to further the certainty of the declining trendline shown in figure 5, which represents the annual number of Big Wind events, future investigations on the Pitot 11 would need to take place. Lastly, in order to make all future wind trends easier to distinguish and in order to understand exactly how summit winds are changing unrelated to summit infrastructure and anthropomorphic wind field discrepancies, it would be ideal for an anemometer to be installed at the exact height and location of the previous anemometer location, so that we may more accurately compare the winds we were recording from 1941-1980 and the winds we have been recording since the anemometer moved to its current location.

WORKS CITED

Bent, Arthur E. Map of Mt. Washington Summit, 1935. *Mount Washington Observatory,* 1935 (Image)

Bent, Arthur E. Mount Washington Summit Map, 1941. *Mount Washington Observatory,* 1941 (Image)

Cronin KP. Wind Climatology of the Mount Washington Observatory (1935-2013). *Plymouth State University*; 2015

Dorsey Jr, H.G. Heated Anemometer for Measuting Wind Velocity. *Mount Washington Observatory,* 1948

Falconer, R.E., 1946: Wind Velocity Measurement, M*ount Washington Observatory News Bulletin, 1, 14, 3-4,* 1946

Gallagher, J.P. Seasonal and Diurnal Variations in Aerosol Concentration on Whistler Mountain: Boundary Layer Influence and Synoptic-Scale Controls. *J. Appl. Meteorol. Climatol* 2011

Howe, John B. Wind Velocity at the Yankee Network Building, Winter '52-'53. *Aeronautical Icing Research Labratory,* 1953

Hugenholtz, C. Wind Hazard in the Alpine Zone: A Case Study in Alberta, Canada. *Royal Meteorological Society,* 2016

McKenzie, A.A. World Record Wind: Measuring Gusts of 231 Miles an hour, *Alexander A. McKenzie,* 1984

Sayen, J. Aerial View of the Summit of Mt. Washington, Looking Southwest. *NH Dept. of Parks and Recreation* 2014 (Image)

von Huene, L., Lubkin, N., Murray, G.L.D., Broccolo, J. Wind, Temperature, and Humidity on Mount Washington, NH, 2022