P1.1 REGIONAL SYNOPTIC CLIMATOLOGY STUDY OF THE MT. WASHINGTON AREA

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1. BACKGROUND

One of the largest field experiments ever conducted in New Hampshire was the Mount Washington Icing Sensors Project (MWISP) of April 1999 (Henson and Anatta, 1999; Ryerson et. al., 2000). This Federal Aviation Administration (FAA) and National Aeronautics and Space Administration (NASA) funded-project, involved scientists from the National Center for Atmospheric Research (NCAR), the U.S. Army Cold Regions Research and Engineering Laboratory (CRREL), the Mount Washington Observatory (MWO), as well as several private research groups and universities. The primary goal of MWISP was to improve prediction/detection of potential aircraft icing by gathering data from remote and in situ sensors.

The MWISP team did not experience the conditions they had hoped for during the month. Having expected a greater frequency of icing in deep clouds, NCAR commissioned Plymouth State College (PSC) to develop a detailed climatology for Mount Washington for the month to determine if April 1999 was anomalous compared to the long-term April climatology (Markle et. al, 2001). When the month was determined to be anomalous, the FAA supported PSC's effort to expand the initial climatology to encompass all months of the year. This paper reports on a portion of the results from this expanded study. These data can help determine the best potential icing times for similar, future experiments in the Mt. Washington region.

2. CLIMATOLOGICAL DATA

Data for the detailed Mt. Washington climatology were collected primarily using the NCAR Reanalysis CDROM data for 1200 UTC each day from 1955 through 1999, as well as NOAA Daily Weather Map series. Data were specifically collected for the summit of Mt. Washington, which stands at 1910m above sea level. The Mt. Washington Observatory was chosen as the location for this study because of its relative height in the atmosphere and the ability to record data year round and in all weather conditions.

Four kinds of data were analyzed for this study. The first was 850mb temperature and relative humidity. These variables were chosen because the mean pressure at the MWO is approximately 810mb and using these data, we could pinpoint times with below freezing temperatures and high humidity, favorable for icing.

Second, was a surface synoptic climatology based upon a New England classification scheme developed by Keim and Meeker (2001). The classification is depicted in Figure 1 and consists of nine numbered weather patterns, which are assigned by their relative position to Mt. Washington. The synoptic Weather patterns are as follows:

1-Frontal Atlantic Return (FAR-1)
2-Atlantic Return (AR-2)
3-Canadian Return (CH-3)
4-Frontal Overrunning-Continental (FOC-4)
5-Modified High (MH-5)
6-Frontal Overrunning-Marine (FOM-6)
7-Gulf of Maine Return (GMR-7)
8-Tropical Low (TL-8)
9-New England High (NEH-9)

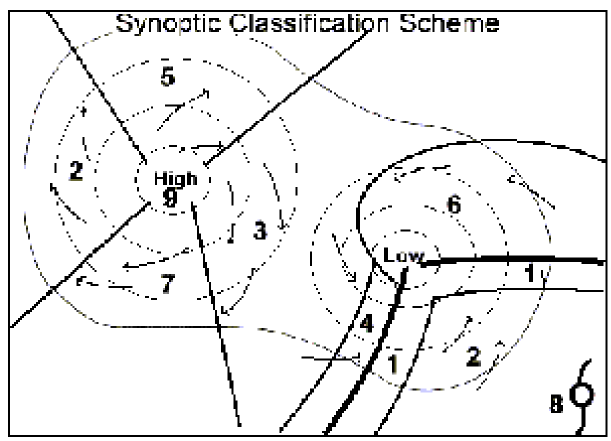

Figure 1. Synoptic Classification Scheme developed by Keim and Meeker (2001), used to classifying Weather events from 1955-1999 from Markle et al. (2001)

The third piece of data collected was the 500mb pattern climatology used to show the general upper air pattern. This classification scheme splits the patterns into troughs, ridges, or zonal flow. Figure 2 illustrates the classification scheme. The six types with the greatest frequencies are as follows:

1 is the leading edge of a ridge
2 is in the center of a trough
3 is on the leading edge of a trough
4 is in the center of a ridge
7 is a zonal pattern
9 is under an upper level low

Note: Classifications 5,6, and 8 were extremely rare and those results are not included.

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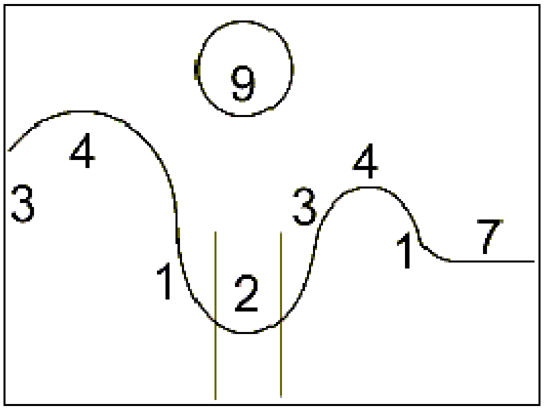

Figure 2. 500mb Classification Scheme. (Markle et al., 2001)

The final data collected were for a 1000-500mb thickness climatology, which was split into two separate parts. The first part was a thickness value analysis that was chosen so as to find the variation in thickness values over the study period and collected using a higher resolution contour interval to easily pick off values. The analysis was also broken down in to five incremental steps beginning with <516 dm and concluding with >552 dm. The second piece of the thickness climatology was a thickness pattern climatology that is based off a classification scheme similar to the 500mb Classifications. However, the zonal flow classification was omitted and any values of thickness above 540 dm were prefixed with a 1 as illustrated in Figure 3. A wider viewing size was chosen to collect this variable so that patterns could be more easily identified.

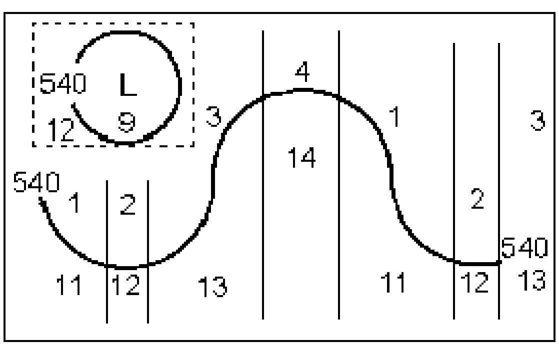

Figure 3. 1000-500mb Thickness Pattern Classification Scheme after Markle et al. (2001).

The thickness climatology was chosen because it provides a general idea of the temperature pattern and a broad view of the vertical temperature structure of the atmosphere.

3. 850MB TEMPERATURE/HUMIDITY ANALYSIS

Since MWN's mean pressure is around 810mb, likely occurrences of icing may be identified at 850mb, one of the "standard" layers in the atmosphere. One would expect months with higher relative humidity and freezing temperatures to be more favorable for possible aircraft icing. Temperature and relative humidity data were gathered from the NCAR Reanalysis (1955-1999), fort 1200 UTC each day. Results for April 1999 showed an 850mb temperature ~2 degrees Celsius above the 45 year average, and relative humidity ~5% above the average. The research was continued to create climatology for the winter months. The 850mb data showed that the conditions needed for icing are readily available on Mount Washington from November thru April. October does experience icing, though the average 850mb temperature would not support many icing events (see Figure 4). The relative humidity values ranged from 62.0% in February to 65.1% in November. Data showed that the highest mean relative humidity values were present during the transition months, especially November and March (see Figure 5).

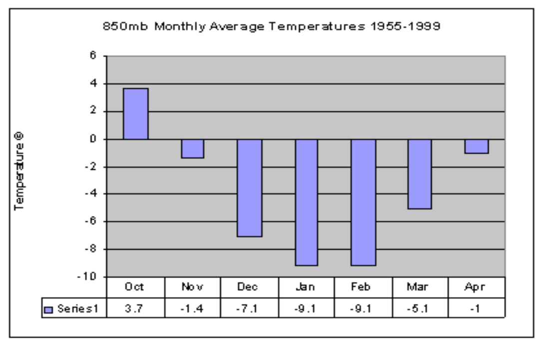

Figure 4. Average monthly 850mb temperatures for the colder months from 1955-1999.

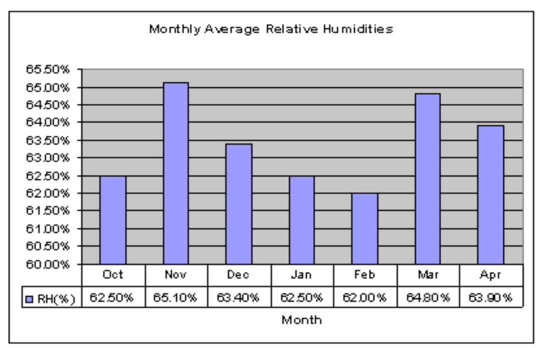

Figure 5. Average monthly relative humidity for the colder months from 1955-1999.

4. SURFACE SYNOPTIC CLIMATOLOGY

Once all the data was collected using the classification scheme above, the data were analyzed by decade to determine dominate synoptic patterns. The same analysis techniques were used to find the overall occurrences for the entire study period. The dominant feature was CH-3, which occurred around 35% of the time in all the months except summer when little icing occurs and AR-2 tends to dominate. All other synoptic type patterns ranged between 5-15% over all months. The CH-3 pattern would introduce brisk northwesterly flow into the region that usually results in cooler temperatures, lower dew points, and clearing conditions. The March Climatology shows the overall trend well in Figure 6. When the 1990s were compared to this overall trend, we found that there was little deviation from the pattern of occurrences. The March comparison graph (Figure 7) makes a good representation of what was found for all other months excluding traditional summer months.

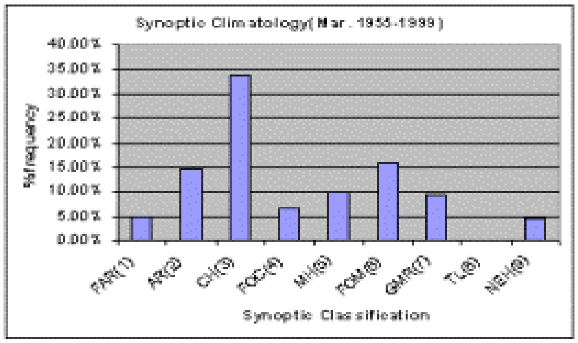

Figure 6. Synoptic type classification occurrences for March.

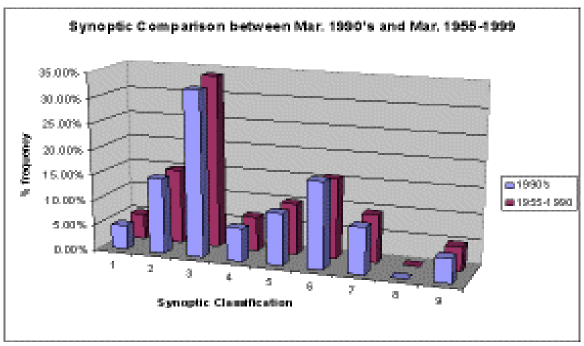

Figure 7. Comparison of March 1990-1999 and March 1955-1999.

5. 500MB PATTERN CLIMATOLOGY

The 500mb pattern climatology was used to look at the general distribution of the mid level wind flow in our atmosphere. The two predominant 500mb flow patterns were classifications (1) and (3). Classification (1) is a northwest flow, whether it is on the front side a ridge or the backside of a trough. Classification (3) on the other hand is a southwest flow supported by the backside of a ridge or the front side trough. We found that during the transition and summer seasons these features occurred roughly an equal amount of the time (see Figure 8).

During the winter month's, classification (3) occurs more often than classification (1) (see Figure 9). Another significant feature was classified as (2). Classification (2) is in the base of a trough. We found that this feature regularly occurs about 12% of the time though climatologically we see more troughs over the Northeast in April than any other month.

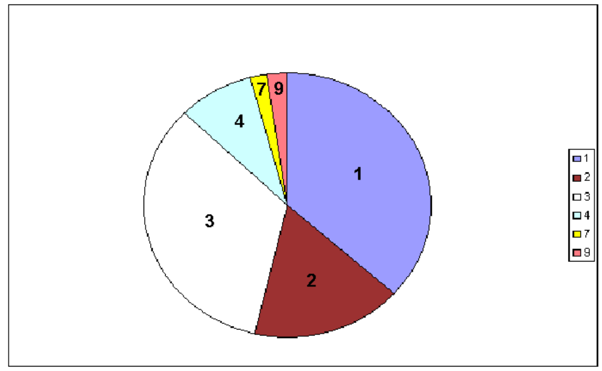

Figure 8. The July 1955-1999 500mb pattern frequency distribution.

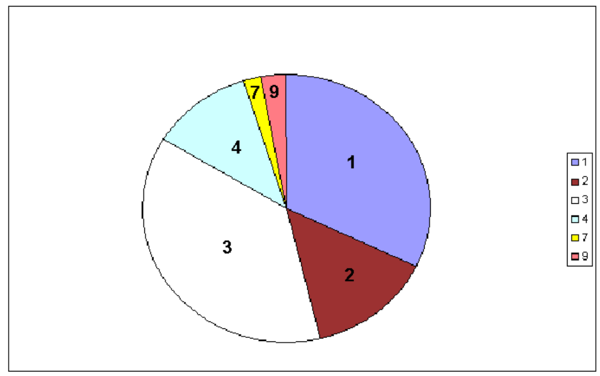

Figure 9. December 1955-1999 500mb pattern frequency distribution.

6. 1000-500MB THICKNESS CLIMATOLOGY

The critical thickness for Mt. Washington for icing on Mt. Washington is around 552 dm. Using the thickness value analysis, several interesting trends were identified. First, The average decadal thickness have increased fairly steadily at a rate of about 2 dm per year since the 1970s and was well above the average thickness for the entire period by the 1990s (See Figure 10). Also, frequencies of thickness above 552 dm during colder months have generally been on the rise since the 1960s (see Figure 11 as an example).

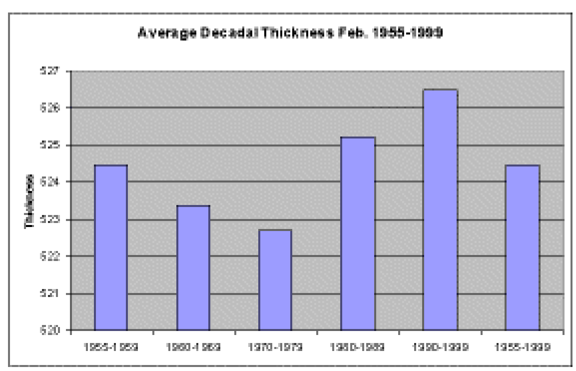

Figure 10. Average decadal thickness and the 1955-1999 average (on the far right) for February.

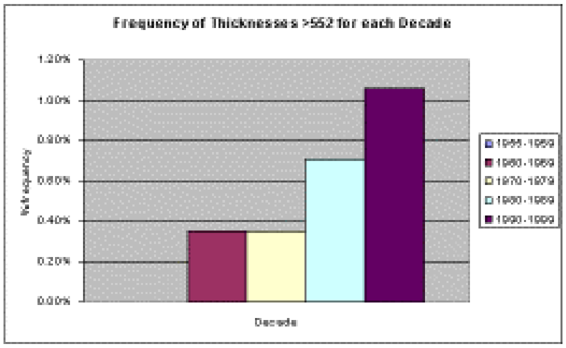

Figure 11. Frequency of thickness greater than 552dm for each full decade for February with the 1960s on the left.

Using the thickness pattern classification scheme, we determined that #3 and #13, in the front side of a trough or back side of a ridge, was the dominate feature during the study period for potential icing months, while pattern #1 and #11, in the front side of a ridge or back side of a trough, dominated during summer months. The more interesting trend is that in all cases the 1990's pattern is skewed away from the study average. Typically, pattern #3 and #13 had a significantly lower frequency while pattern #1 and #11 similarly became more frequent (see Figure 12). Occasionally, patterns were difficult to classify do to flat features. An additional zonal flow category used in the future would greatly simplify the classification process and promote more accurate data

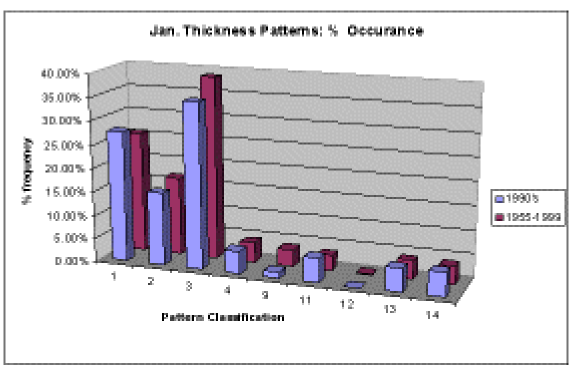

Figure 12. January thickness patterns: frequency of occurrence. This example, from January, shows the overall frequency of the whole study period compared to that of just the 1990s.

7. SUMMARY/CONCLUSIONS

This climatology indicates that Mt Washington is dominated by both northwesterly flow from Canada and a good deal of east-northeasterly flow off the northern Atlantic. These conditions are generally needed for icing events to occur. The 1990s showed a slight increase in the amount of warm advection occurring for the decade, which may be one reason that the April 1999 MWISP had fewer icing events than expected.

Upper air analysis showed that Mt. Washington usually resides in the backside of a trough. This introduces cold air advection into the region and should allow for several consecutive days of icing potentially to occur. The temperatures at 850mb indicate November through April can typically support icing conditions. This is especially true for November and March when relative humidity values also tend to be at their highest levels.

The next step in the process will be to analyze hourly surface data for Mt. Washington. Specifically, current weather conditions have been collected with emphasis on freezing fog days. This can then be compared to the completed climatology to better deduce the conditions in which icing occurs and to make a better recommendation for the best times for icing to be studied in the future.

More detailed and additional results of this research can be found at the following URL address: http://snow.plymouth.edu/KMWNnew/MWNpage.html

8. ACKNOWLEDGMENT

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9. REFERENCES

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