P 1.4 A Climatology of Weather Influences on Electric Power Outages in New Hampshire

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1. Introduction

It may be self evident that weather can often have an adverse affect on the delivery of electric power. However, very little attention has been given to understanding the role of weather on power outages in a comprehensive, climatological fashion. In this study, the Plymouth State University Meteorology Program and Public Service of New Hampshire (PSNH) are collaborating to gain a further understanding of the exact types of weather that cause power outages in the PSNH network. The ultimate goal of this research is to support resource management decisions when adverse weather conditions are being forecast. As with any resource management endeavor involving weather forecasting, it is important to know and understand the climatology of past events.

Therefore, eight years of PSNH power outage data (Jan. 1996- Aug. 2004) are examined to develop a climatological composite of weather events that cause major power outages in New Hampshire. Only major outage events (> 100 troubles) are being examined. Over this period a total of 68 major outage events have been attributed to adverse weather. In these eight years, four different types of weather events have been identified to cause power outage: wind storms, winter storms (ice, sleet, snow and wind), thunderstorms, and heat waves. A climatological/statistical summary of all the weather events that cause outages will be given in section 2. A closer look at the average weather conditions for winter events is given in section 3. Finally a summary along with a discussion of the potential usefulness of the data in day-to-day operations is given in section 4.

2. Climatological Summary

The first task was to categorize and examine the inter-annual and monthly occurrence of weather events that are categorized by PSNH to be "storms" and "major storms". In order to do this, the raw data regarding the number and location of outages sorted by PSNH Area Work Centers (hereafter AWCs) had to be examined thoroughly.

Examination of all 68 events showed that there are four major types of weather that cause outages in the PSNH network: winter storms, wind storms, thunderstorms, and heat waves. The number of each type of event is given below in Table 1.

Winter Storms	Wind Storms	Thunderstorms	Heat Waves
20	31	15	2

Table 1. Number of each type of weather event causing PSNH system outages from 1996-2004.

Wind storms are the most frequent and heat waves are the least frequent. However, PSNH has only just begun to track electricity outages due to heat waves in the last few years (Dan Pike, personal communication). PSNH experiences an average of 8 storm events causing outages per year with a high of 14 events in 2002 and a low of 5 events in 2003. The monthly variability in events and event type is shown in Figure 1. Figure 1 shows that weather events that cause outages can happen in each month of the year. However, these events are most common in the late winter (Feb., Mar.) and fall (Oct. and Nov.) with a minimum in January and the late summer months (August, and September). This is a very interesting result, because the frequency of mid-latitude cyclones affecting the Northeastern U.S. is known to peak in the mid-winter (Jan., Feb.). Our initial hypothesis was that most wind and winter storm damage is associated with mid-latitude cyclones. So it remains unclear why mid-winter cyclones associated with the peak climatological frequency might not cause as much damage. A closer inspection of Fig. 1 shows that Winter Storms are most frequent in Feb/March and November, while wind storm events are most frequent in fall (Oct., November). Not surprisingly, thunderstorm events only occur in the summer months (May-August) with an early season peak in June and heat waves events have only occurred in July and August.

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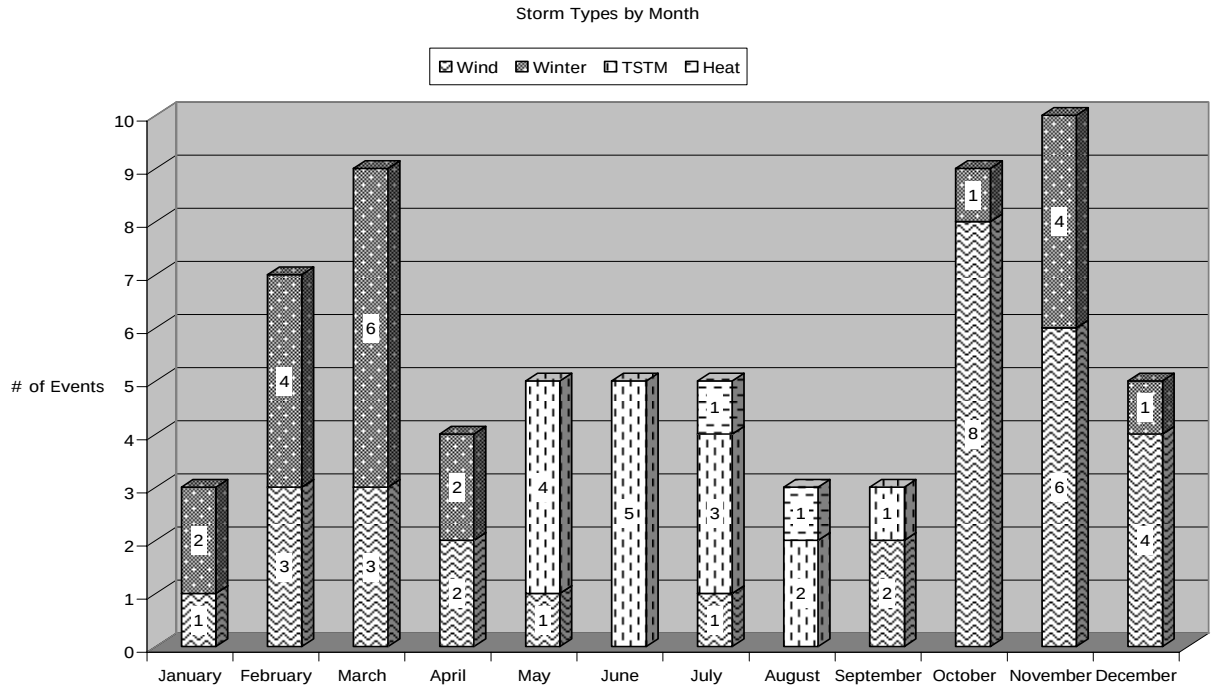

Figure 1. Monthly histogram of all weather event types causing major outages in the PSNH network for the 8 years (1996-2004).

3. Winter Storm Events

The results of the above analysis of the monthly variability of event types lead to several interesting questions: 1) What causes winter storm events in early winter and spring to more frequently cause damage to PSNH than mid-winter storms which ought to be most frequent?; and 2) Why do wind storm events seem to cause the most outages most frequently in the Fall? In order to answer these questions and address the goals of the project, average weather conditions will eventually examined for each storm type. In these preliminary results, we chose to look first at the average weather conditions associated with winter storm events because they provided a manageable first sample to work with (20 events) and any initial findings might be put to use this winter season.

3.1 Data and Methods

A myriad number of weather factors could be examined in order to identify significant forecastable factors associated with winter storm event outages. Initially we chose to focus on the hourly surface weather data (METARS). Hourly weather data for each event was extracted from the online Plymouth State University Weather Center (hereafter PSUWX) archive for the 3 days surrounding the event (day before, day of, and day after). Unfortunately, the PSUWX archive only has data from 1998 to the present. A suitable source for the hourly data from 1996 has not yet been identified so the analysis of winter storms only includes 12 of the 20 events. Results of analyses of these surface hourly data are presented below.

Daily precipitation, snowfall, and snow depth data was also collected from the National Weather Service's Cooperative Observing Network. This data is available for all nine years and has been extracted for the 5 days surrounding each case from the online archive and the National Climatic Data Center (NCDC). In addition to surface weather data, upper-air data from the Gray, ME sounding site has been extracted from the PSUWX. Analyses of these data sources are ongoing and results will be available soon.

In order to study the regional variability in weather factors, the PSNH service area was subjectively divided into four main regions: North, Central, South, and Coastal. Winter storm event averages and variability for each surface hourly variable was calculated for all of New Hampshire and for each separate region. In addition, it is important to study and understand the evolution of each of these factors for each event. However, since the events do not all occur at the same time of day, once cannot just compare 11 UTC for one event to 11 UTC at another event. Therefore, the time when the most troubles were being reported was identified for each winter storm event. This time (labeled t=0) will be identified here as time of maximum outage. Averages and variability about the

average for many weather factors was calculated at the time of maximum outage and for 3 hour intervals before and after this time (i.e., t-3, t+3) etc…

3.2. Winter Storm Events (Preliminary Results)

As noted above, we assumed a priori that winter storm events are going to be associated with surface low pressure systems. Of interest, therefore, is the location and track of the surface low pressure systems that are associated with the winter storm events. Examination of the storm tracks (not shown) indicates that for nearly all storms (except two) the surface low pressure system moves to the south and east of New Hampshire quite near to the southern New England coast. Many of the storms follow the familiar Nor'easter track along the coast. This result is climatologically reasonable as this "coastal" track is a well known cyclone track (Zishka and Smith, 1980). One notable exception to this track is the January 1998 Ice Storm (Gyakum and Roebber, 2001) for which the surface low pressure system moved north and west of New Hampshire. Since many more storms in any year follow this coastal track than are identified here as being associated with outages, there must be other important weather factors that determine if winter storms are going to cause an outage. However, it seems likely that storms that are forecast to move over or north of New Hampshire are unlikely to cause a winter storm outage.

Since the winter storm outages do seem to be associated with surface low pressure systems we might hypothesize that they might be unusually deep low pressure systems or associated with rapid deepening. Our analysis of the sea-level pressure data doesn't support this notion. In general the lowest pressures occur from the time of maximum outage to 6 hours later and this is true for all regions with an average lowest pressure (from land stations only) of only 1005 hPa. These values of the average pressures are not particularly low, again supporting the notion that the center of lowest pressure is not occurring over New Hampshire. Rapid deepening is not evident either over the state of New Hampshire.

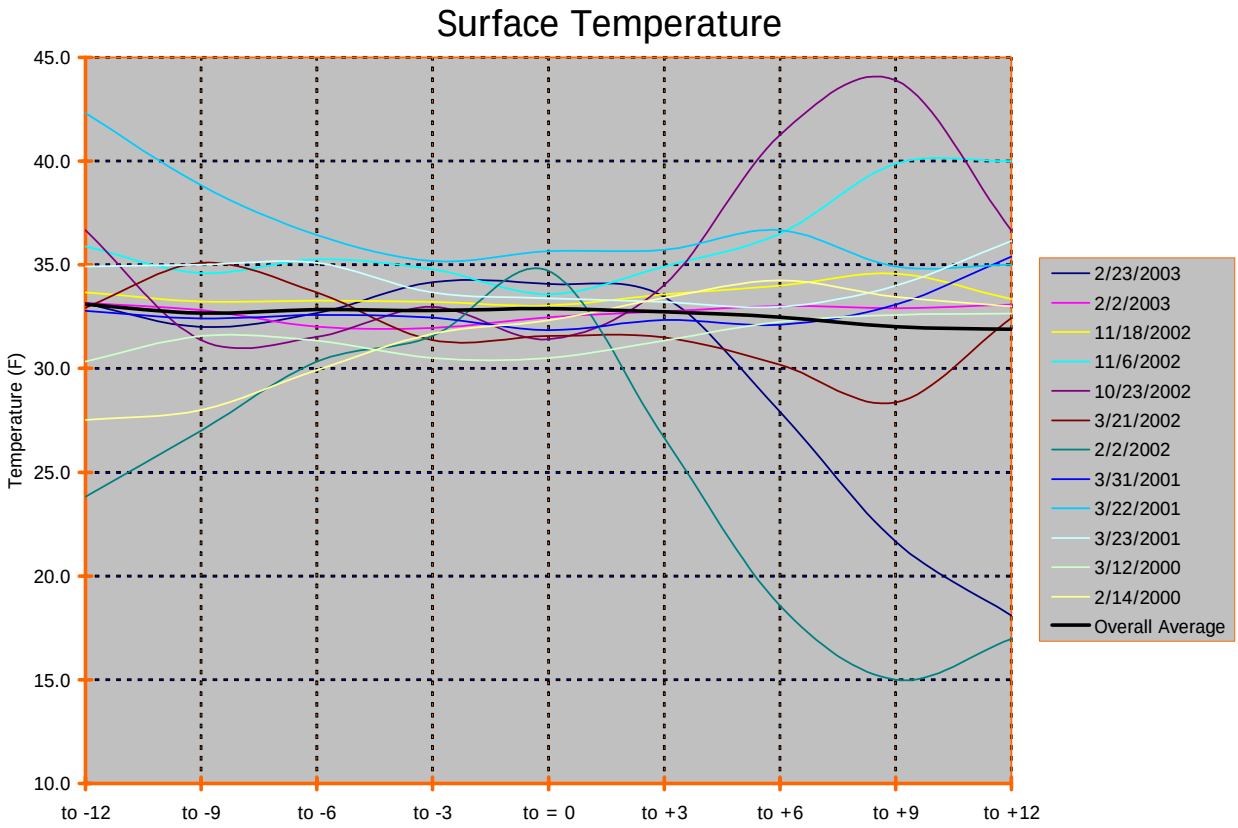

Figure 2. Evolution of the hourly surface temperatures in winter storm events from twelve hours before maximum damage (to-12) to twelve hours after maximum damage (to+12) for all 12 events from 2000-2003.

Another important weather factor to examine was wind speeds and wind gusts. Examination of the PSNH reporting data showed that much damage to the power lines during winter storm events comes from ice/sleet/snow on the lines and on tree limbs which subsequently fall on the lines. Average wind speeds are generally fairly low throughout the duration of an event with averages only around 6 kts. This average goes up substantially for the 12 hours after the time of maximum outage, but certainly not before. Again this result compares favorably with the surface low pressure tracks as the strongest pressure gradient and hence the strongest winds are usually found to the northwest of the low center. However, these are not very strong wind speeds. In fact, the distribution of winds speeds is highly skewed toward lower speeds with quite a high frequency of hourly reports during winter storm events occurring with wind speeds less than 5 kts (not shown).

Similarly, we found that wind gusts of 15-30 kts often accompany the storms. There is only a slight increase in the wind gust speeds during and event and this is concurrent with the slight increase in the average winds speeds from the time of maximum outages over the subsequent 12 hours. It seems, therefore, that winter storm events are not characterized by low pressure, rapid pressure changes, high average wind speeds, or high peak gusts.

When we examined the temperatures, however, we found a significant result. Figure 2 shows the evolution of hourly average temperatures for the winter storm events. We can see that on average, the temperature in winter storm events is primarily between 30 and 35 F in the hours when maximum damage is occurring (t=0). Our first preliminary conclusion therefore is that winter storm event damage is primarily caused by wet heavy snow, sleet, and frozen precipitation that accumulates on trees in fairly light wind conditions. Winds can actually have a positive contribution in minimizing the outages by causing the accumulated snow on limbs to blow off (Dan Pike, personal communication). Examinations of several null cases (cases of significant winter snowfall that did not cause major electrical outages shows that the temperatures are generally colder (25-30 F) and the winds are a bit higher suggesting that lighter snow with a higher snow to liquid ratio falls with colder temperatures and does not weigh heavily on limbs and lines causing the outage.

4. Summary and Future Work.

Eight years of weather data and electric power outage data from PSNH have been collected and analyzed. PSNH experiences on average 8 major power outages per year due to weather. There are four major types of weather that can cause outages: winter storms (ice, sleet, snow), wind storms, thunderstorms, and heat waves. In general, winter and wind storms affect the PSNH network most in the fall and early spring, but not during mid-winter. Thunderstorms and heat waves occur during the summer months.

A preliminary examination of winter storm events shows that these events are associated nearly always with mid-latitude cyclones that pass south and east of New Hampshire. These cyclones generally have light winds (less than 6 kts) with moderate gusts and are not associated with low sea-level pressures over land or with rapid pressure falls. However, when the most damage to the PSNH network is occurring from winter storms the temperature has always been between 30-35 F. Our first preliminary conclusion therefore is that winter storm type damage occurs from “wet snow” conditions in which the wet heavy snow with high liquid water content weighs down power lines and tree limbs causing outages.

Future work on this project will continue to examine the wind, thunderstorm and heat wave events to see if there are more identifiable and forecastable characteristics associated with these events in the climatology. Once each event type has been studied, we will collaborate with PSNH to develop a tool for their managers to put this climatological information to use in their day-to-day operations.

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