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8.5 PERFORMANCE OF THE HAINES INDEX DURING AUGUST 2000 FOR MONTANA

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1. INTRODUCTION

The Haines Index, introduced by Haines (1988) as the Lower Atmosphere Severity Index, is designed to gauge how readily the lower mid-troposphere (500 to 4500 m AGL) will spur an otherwise fairly predictable fire to become erratic and unmanageable. Based on stability and moisture, the Haines Index (hereafter, HI) takes on integer values from 2 to 6, with 2 being very low risk and 6 being high risk. Since its introduction, several studies have examined the performance of the HI. Werth and Ochoa (1990) saw a positive correlation between daily rate of spread for the 1989 Lowman fire in Idaho and daily HI values. In a more qualitative sense, Saltenberger and Barker (1993) examined the 1990 Awbrey Hall Fire in Oregon, and noted that when the Index was high the fire displayed "extreme behavior...rapid growth" and when the index was low, the fire severity diminished.

While the latter two studies examined the behavior of the HI and specific fires, Werth and Werth (1998) presented a 5-year climatology of the HI for the western United States. They found that the frequency of 6's varied widely, being as high as 31% at Ely, Nevada. This high frequency of 6's raised questions about the value of the Index in the region, and whether the Index was valid for all regions of the U.S.

During the summer of 2000, the HI was not too different from the climatology of Werth and Werth for Lander, WY and Boise, ID. It averaged considerably higher at Great Falls, MT. Compared to Werth and Werth's (1998) results, Index values of 5 or more at Lander, Boise, and Great Falls were 12%, 0%, and 54% high, respectively. Under these atmospheric conditions, the number of fires and total number of acres burned were both well above the 1993-1997 averages (Table 1).

In contrast, during the summer of 1999, the HI was unusually high for the Northern Rocky Mountain region (Potter and Martin, 2001). Compared to Werth and Werth's (1998) calculations, HI values of 5 or greater occurred 30% more often at Lander, WY; 70% more often at Boise, ID; and 81% more often at Great Falls, MT. The number of fires in the region (Table 1) was slightly below the 1993-1997 average, and acres burned were about half the 1993-1997 average. In short, though the HI was unusually high, the number of both fires and acres were low.

TABLE 1. Number of fires and area burned in the Northern Rocky Mountains region (ID, MT, ND) for selected years.

	1993-1997 Average	1999	2000
Number of fires	4423	3025	5188
Area burned	459 012	201 473	2 304 600

This contrast between 1999 and 2000 suggests the possibility that the HI failed for one or both years. One must consider the purpose of the HI, however. First, it reflects the potential for growth and does not account for ignition or fuel conditions. Second, it is specifically meant only to describe plume-dominated fires and does not apply to situations with strong winds.

There are several possible explanations for the apparent conflict in these statistics. Most likely, the contrasting numbers are the result of several factors – wind, fuel conditions, number of ignitions, to name a few. It is a complex question with many facets.

Rather than attempt to assess all of these possible contributions, we will focus on one specific question: did the HI show some ability to predict fire growth during the summer of 2000? More precisely, did the daily HI have a positive correlation with the daily rate of growth for fires in the summer of 2000 on low-wind days?

2. METHODS

Our study used two types of data, one set meteorological and the other a record of daily fire-area maps. The fire data consisted of daily GIS

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maps of the Burnt Flats, Wilderness Complex, and Valley Complex fires that burned in western Montana and western Idaho during the month of August 2000. On some days, one or more of the fires had negative area gains, according to the GIS records. This could happen for a number of reasons, from reporting errors on one day to a change in the method of determining area between two days. For our purposes, any day and fire that reported a negative change in area from the previous day was omitted for that day.

To reduce the influence of factors like suppression efforts, topography (slope), and nonuniform fuels for an individual fire, we used the average growth rate of all three fires. Because the fires were different sizes, simple area burnt per day was not a comparable statistic. For a given rate of spread, a fire with a long active front will yield a larger burn area for a day than a short front would yield. Instead, we used two measures of fire growth that normalized the three fires, to a limited extent: percent of final area burnt on a given day ($\Delta A\%$) and the fractional increase of fire perimeter over the previous day ($\delta f_p = \delta p/p$). Figure 1 shows $\Delta A\%$ for the individual fires from the study, and fig. 2 shows δf_p.

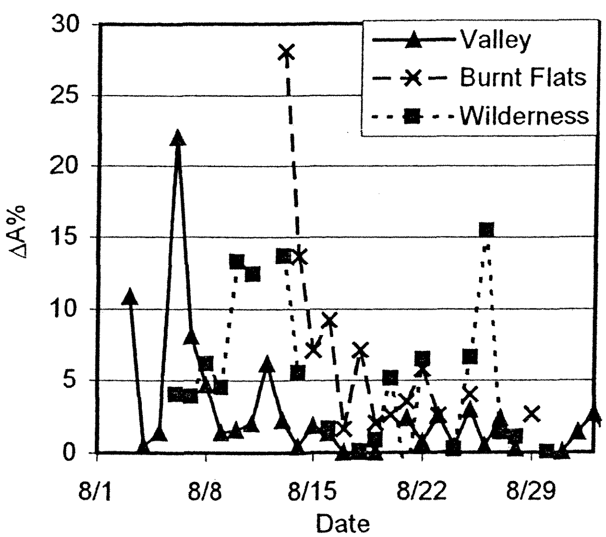

FIGURE 1. Percent of final area burnt ($\Delta A\%$) on each day for the 3 fires examined in this study.

The meteorological data consisted of 0000Z radiosonde data from Riverton, WY (RIW, elev. 1688 m ASL), Great Falls, MT (TFX, elev. 1130 m ASL), and Boise, ID (BOI, elev. 871 m ASL) for the days on which fire areas were available. These three stations form a roughly equilateral triangle in the region where the fires occurred. Since 0000Z on a given date corresponds to the afternoon of the previous date for the study area, we matched the 0000Z sounding for a given date with the fire area data for the previous date in the fire record.

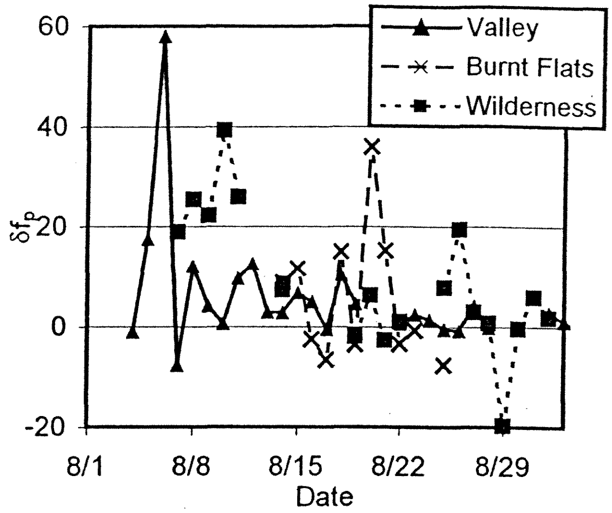

FIGURE 2. Daily values of δf_p for the three individual fires considered in this study.

The first step in analyzing the data was to determine which days were appropriate for a test of the HI, in the sense that they were low-wind days. To do this, we computed the ratio of stability to wind as done in Goodrick et al. (2001). This involved normalizing the stability and transport wind components of the Lavdas (1986) Atmospheric Dispersion Index each by their average values for the month of August, then taking the ratio of these normalized values. In all subsequent analysis, unless otherwise noted, only days that were stability dominated were considered. From each of the remaining days, we computed the A and B components of the (high elevation) HI and the full HI, for each of the three radiosonde sites. Figure 3 shows the daily HI values for the 3 study stations, for those days determined to be low-wind.

Once any days with negative fire growth rates, missing radiosonde data, or strong winds were eliminated, we compared the HI from each station with fire growth. One correlation coefficient, *r*, was computed for each fire growth-radiosonde station pair. Because of the limited sample size involved, the results are subject to the many complications of small-sample statistics. In particular, one data point can strongly influence the results, and even correlations that look strong (close to 1) may be due to pure chance. For these reasons, the results should be considered as tentative or exploratory.

The HI presents a particular challenge for correlation studies of this sort. Because the Index can only assume one of 5 values, any analysis with more than 5 days will necessarily include more than one fire-growth value for a given HI value. While the usual method of computing correlations when there are duplicate values of one member of the paired data is to use a nonparametric measure like Spearman's ρ, the data in this study had so many duplicate values of the HI (9 out of 15 HI values for the RIW data were 6's, and 4 values were 5's), even Spearman's ρ was not a good test parameter.

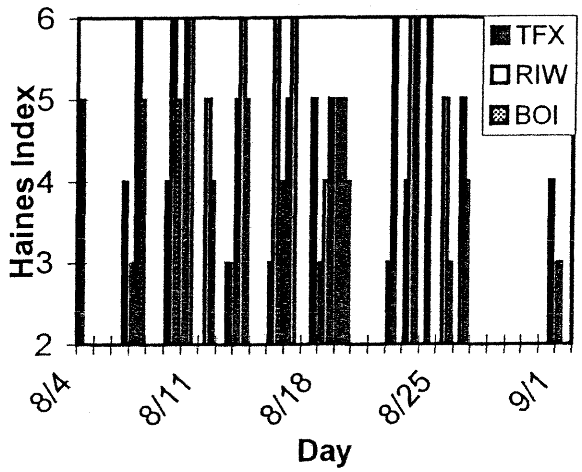

FIGURE 3. Daily HI values for TFX, RIW, and BOI.

Since the focus of the study was the HI, we could not very well drop it from the analysis. Instead, we examined the correlations between the 700 mb to 500 mb temperature difference (ΔT)and fire growth, and between 700 mb dew-point depression (DPD) and fire growth. The DPD and ΔT are the variables that determine the Haines Index; they are both continuous variables, unlike the HI.

Because the decision of whether a particular correlation is "significant" is largely subjective, we decided to use the closest thing to an objective measure we could find. Rather than set our own subjective standard, we will simply report the various *r* values we obtained. As a rough benchmark, we note here that Werth and Ochoa (1990) (subjectively) considered the correlation they saw between HI and daily rate-of-spread sufficient to make the HI valuable, and that correlation coefficient (based on data in their paper, computed by ourselves) was r=0.46, with n=11 data points.

3. RESULTS AND DISCUSSION

Table 2 summarizes the correlation coefficients we obtained from the HI data. The results for RIW were highest of the 3 stations for both measures of growth. BOI was intermediate of the 3 stations, with an extremely low correlation for δf_p. TFX had a low positive correlation for $\Delta A\%$, and a negative correlation for δf_p. The correlations for RIW were slightly lower than what Werth and Ochoa (1990) found, but not dramatically so.

TABLE 2. Correlation coefficients, *r*, for all three stations and both measures of fire growth. The numbers in parentheses after the station symbols indicate the sample size for each computation.

	$\Delta A\%$	δf_p
BOI (15)	0.24	1.8×10^{-4}
TFX (13)	0.06	-0.02
RIW (14)	0.41	0.33

The results of the correlations between ΔT and DPD appear in Table 3. The negative correlations for DPD at BOI and TFX and both $\Delta A\%$ and δf_p were surprising. Closer inspection of the data revealed that these were due to one day's growth of the Valley Complex fire. Removal of that day's growth improved the correlations for RIW and TFX noticeably, but correlations between growth and ΔT at BOI became weaker. This dependence on an individual point, and the size of the data set suggest that none of the correlations are particularly robust.

TABLE 3. Correlation coefficients, *r*, for ΔT and DPD at all three stations and both measures of fire growth.

Station	Parameter	$\Delta A\%$	δf_p
BOI	ΔT	0.29	0.29
	DPD	-0.09	-0.36
TFX	ΔT	0.12	0.11
	DPD	-0.10	-0.08
RIW	ΔT	-0.11	0.14
	DPD	0.45	0.29

4. CONCLUSIONS

Our examination of correlations between fire growth and the HI yielded positive correlations for all three stations when correlated with $\Delta A\%$. The correlation was very weak for TFX, but for RIW it was comparable to that found by Werth and Ochoa (1990). Correlations between the HI and δf_p were weaker, and even negative for TFX.

In the introduction, we noted that there were a range of factors that could have influenced the utility of the HI for the fires we considered (or any fires). Evidently, the station used to compute the HI is also an important factor. We did not attempt to interpolate the meteorological data from the 3 radiosonde sites to the location of the fires, and perhaps this would have produced a more reasonable value of the HI for testing correlations. Similarly, if one were to use soundings from a gridded model for a point closer to each fire, the results might tell more about any correlation between HI and fire growth.

The brief examination of the raw data used to compute the HI indicated that it did correlate with the growth of fires, better at RIW again than at the other stations. There has been some discussion in the fire weather community about "opening up" the top end of the HI, since some locations so often get values of 6. Because of the small sample size and other complicating factors involved in this study, our results should not be construed as support for that idea. Such a step should only be taken, we feel, if it is carefully researched and done on a uniform basis across the region and/or nation.

For any future research of this nature, it will be critical to have reliable, lengthy records of daily fire activity. The negative burn areas and periodic windy conditions during the study period both reduced one month and three fires' worth of data to 10-15 days worth of usable data, a very small sample size for a reliable statistical study. Heterogeneous surface conditions within the burn areas and differences between the radiosonde sites and fire sites further complicate any attempts to correlate atmospheric conditions with fire behavior.

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