J2.7 COMPUTATION OF THE LOW ELEVATION HAINES INDEX

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1. INTRODUCTION

Haines (1988) proposed an operational index for use in wildland fire management, calling it the Lower Atmospheric Severity Index. The Index, since renamed the Haines Index and referred to in this paper as the Index or HI, reflects the stability and dryness of air above the ground and is intended to reflect the likelihood of plume dominated fires becoming large or displaying erratic behavior. Haines based the construction of the Index on earlier work by Brotak (1976) that showed a correlation between large fires in the eastern United States and (1) temperature difference between 950 hPa and 850 hPa, and (2) 850-hPa dew point depression.

Haines designed the Index to capture atmospheric conditions above the ground using temperature and dew point measurements readily obtained from upper air soundings across the United States. In doing this, he created three variants of the Index to account for differences in surface elevation. For areas in the eastern United States excluding the Appalachians, he used the same levels Brotak considered, 950 hPa and 850 hPa, to create the "low elevation variant." He calibrated the HI using these levels and, based on a limited climatological comparison, set thresholds that appeared to discriminate well between typical conditions and conditions with high potential for large or erratic fires.

In 1991, however, the National Weather Service introduced a new mandatory level at 925 hPa. With this change, temperature observations for the 950-hPa level became less common. At present, reports of 950-hPa temperature are infrequent. This change raises the question of how the HI should be computed for low elevation locations, since the original input data are not available and various solutions have their advantages and disadvantages. There is currently no agreed upon standard in the fire and fire-weather communities, and an informal survey of web sites indicated several methods in use when this study began. As a result, practitioners may not know how the HI value they received was computed.

This paper describes an analysis of three different solutions to the question of how one should compute the low elevation variant of the Haines Index.

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2. METHODS

The low elevation Haines Index converts 00 UTC 950-hPa to 850-hPa temperature difference and 850-hPa dew point depression each to an integer value between 1 and 3, then adds these to obtain a total Index value between 2 and 6. Higher values indicate greater risk of large or erratic fires. For the temperature component, the thresholds between component values of 1 and 2, and between 2 and 3, are 4 ºC and 8 ºC, respectively.

We examined three options for computation of the Index's temperature difference component.

- Use 925-hPa temperature in place of 950-hPa temperature with no change in the thresholds.
- Interpolate 950-hPa temperature from the surface and 925-hPa temperature observations with no change in the thresholds.
- Adjust the Index thresholds to allow direct use of 925-hPa temperature.

This comparison required soundings with both 950-hPa and 925-hPa temperature observations. A previous study by two of the present authors had performed quality control on National Climatic Data Center sounding data spanning 1958-2000 for locations between the Rocky Mountains and the Appalachians (Winkler et al., in preparation). The overlap between this region and Haines' low elevation region yielded 18 stations with usable soundings (Fig. 1). While we analyzed the entire 1958-2000 period, the majority of the soundings that contained both 925-hPa and 950-hPa observations came from the period 1992-1997, shortly after the time when the 925-hPa level was introduced as a standard level. The analysis examined 39,818 soundings from 00 UTC.

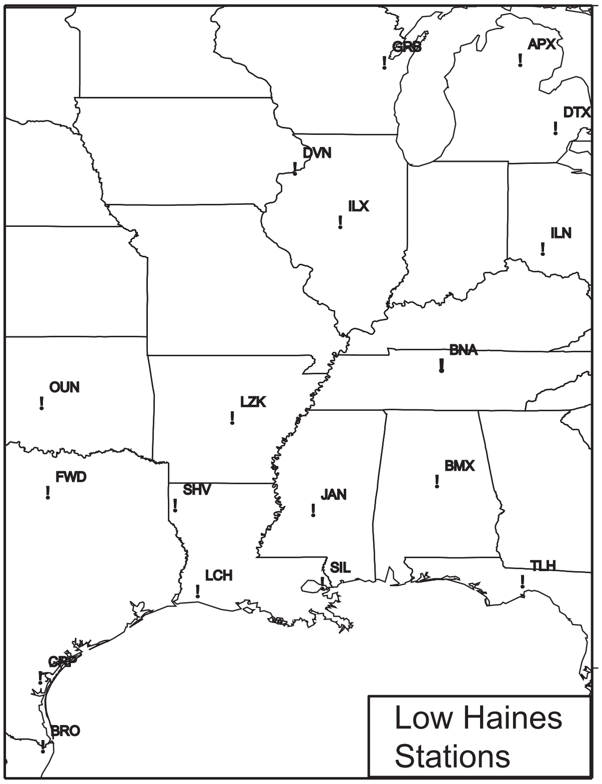

Figure 1. Radiosonde stations used in this study.

To compare the three alternative methods with the original Haines Index method, we computed four values for the Haines Index for each sounding. First, we computed the original Haines Index, using the observed 950-hPa temperature. Second, we used the 925-hPa temperature as a direct substitute for 950-hPa temperature in the "925-hPa raw" approach. Third, we used a log-pressure interpolation between the surface and 925-hPa temperatures to obtain a value at 950 hPa for the "interpolation" approach. Finally, we adjusted the thresholds originally used by Haines to demarcate values of 1, 2 and 3 for the *A* component of the Index for the "new thresholds" approach.

As noted above, Haines originally used temperature difference thresholds of 4 ºC and 8 ºC. As a rough approximation, the layer from 925 hPa to 850 hPa is ¾ of the depth of the original layer, so we chose new thresholds that are ¾ of the original values. The original 4 ºC and 8 ºC thresholds became 3 ºC and 6 ºC, respectively. (While the interpolation approach uses log-pressure interpolation between the surface and 925 hPa, the new thresholds approach is mathematically equivalent to linear (in pressure) extrapolation of the 850-hPa to 925-hPa temperature lapse rate to 950 hPa.)

We compared the alternative versions with the original version of the Haines Index for each sounding to determine how often they agreed or disagreed. The better the agreement, the more faithful that alternative was to the original Index. We consider only those cases where the original Haines Index was a 5 (moderate potential for large or erratic fires) or 6 (high potential for large or erratic fires). These are the cases where an inaccurate value is most likely to be a fire behavior or firefighter safety concern.

3. RESULTS

We examined the results of the analysis in terms of how often a given method differed from the original HI value. On an annual basis, when the original HI value was a 5 or 6, the 925-hPa raw method yielded a value that was lower than the original HI value 75% of the time; the interpolation method was low 8% of the time; and the new threshold method was low 17% of the time. The 925-hPa raw and interpolation methods yielded values that were higher than the original HI value less than 1% of the time, and the new threshold method was too high approximately 1% of the time. There is a seasonal variation in the accuracy of the methods (Table 1), but in all seasons the 925-hPa raw method performed the worst and the interpolation method performed the best. The error rate of the 925-hPa raw method is always substantially greater than either of the other methods.

Alternative method	Season	Underestimation Frequency
925-hPa raw	Spring	78
	Summer	81
	Fall	74
	Winter	68
Interpolation	Spring	3
	Summer	4
	Fall	14
	Winter	12
New Thresholds	Spring	11
	Summer	15
	Fall	19
	Winter	23

Table 1. Frequency (in percent) that the alternative methods of computing Haines Index underestimated an original HI value of 5 or 6.

The denominator in the above percentages is the number of occurrences of original HI 5s or 6s.

The numerator in each case reflects the subset of that number where an alternative method gave a lower value compared to the original method. While these fractions are scientifically interesting and insightful and are what are most often thought of as an "error rate", they are not the most useful way to state the results from an operational perspective. Users of the HI are not interested in how often a "real" 5 or 6 is miscalculated. Rather, they need to know how often the value they obtained from some alternative method is likely to understate the "real" risk of large or erratic fire. In short, the ratio the users need has "number of occurrences of the alternative method yielding 4" in the denominator and "number of times the true value is a 5 when the alternative gave a 4" in the numerator. The remainder of this discussion examines the analysis in this way.

Figure 2 shows the spatial pattern of errors for the 925-hPa raw method. The percentages indicate how often the 925-hPa raw method produced a 4 when the original method produced a 5 – i.e., 4s that should have been 5s. In all seasons, errors are less common along the Gulf Coast and along the lower Mississippi River. Error rates are also slightly lower in the Great Lakes region, but this may be due to a single station (Alpena, Michigan). Results for 5s that should have been 6s have similar spatial patterns (not shown).

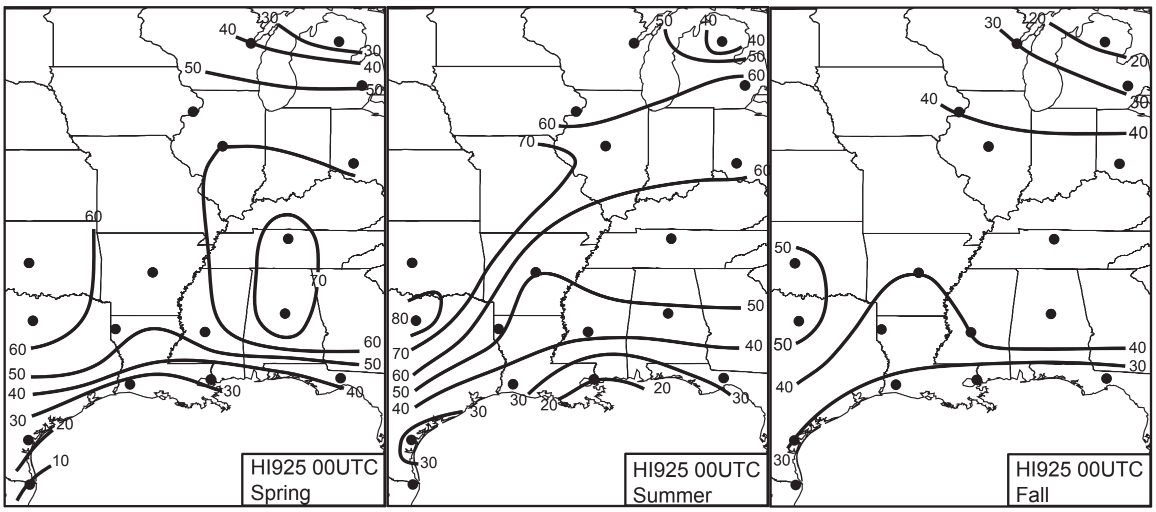

Figure 2. Seasonal percentages of the 925-hPa raw method Haines Index values of 4 that were 5 when computed using the original formulation of the Haines Index.

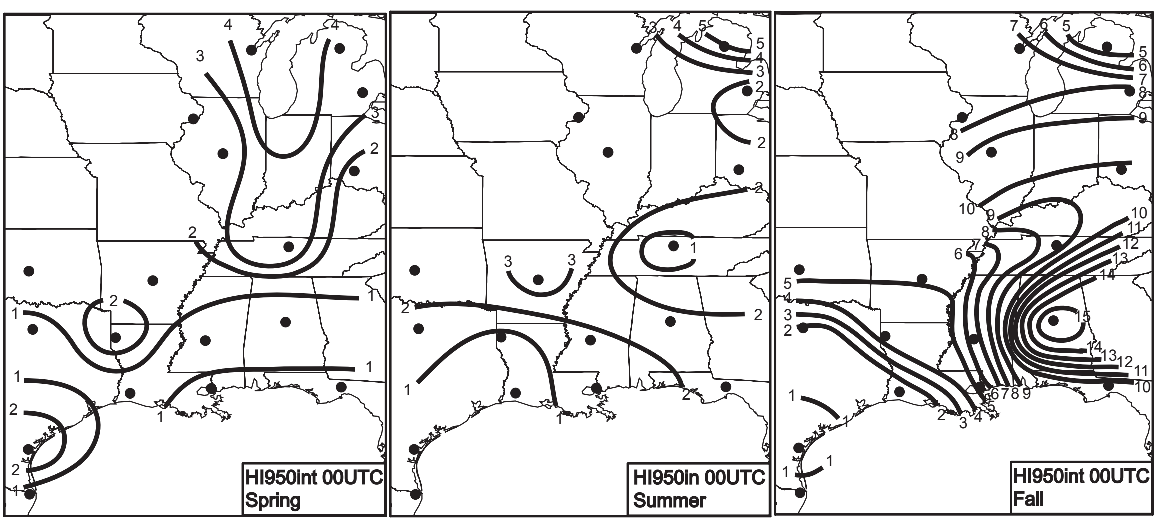

Figure 3. Seasonal percentages of the interpolation method Haines Index values of 4 that were 5 when computed using the original method of computing the Haines Index.

Figure 3 is similar to Figure 2, but shows results for the 950-hPa interpolation method. (We show no spatial results for the new thresholds method since this method was intermediate between the other two in terms of accuracy and is not in common usage.) The most conspicuous feature in the interpolation errors is the bull's eye around Birmingham, Alabama in the fall. Less obvious is the reversal in the error gradient across the Great Lakes between spring/summer and fall. Also, the lower rates along the Mississippi and Gulf Coast seen with the 925-hPa raw method do not appear in the interpolation method.

We examined the high error rate at Birmingham in more detail, to determine what might cause it. An interpolated HI lower than the true HI means the difference between interpolated 950-hPa and actual 850-hPa temperatures is smaller than the difference between the actual 950-hPa and 850-hPa temperatures – i.e., the interpolated temperature is lower than the true temperature at 950 hPa. That, in turn, requires that the surface to 950-hPa layer is more stable than the surface to 925-hPa layer.

We computed the stability of the surface to 950-hPa and the surface to 925-hPa layers for the fall soundings at Birmingham and Shreveport, Louisiana, the latter being nearby but having a much lower error rate. The results indicated that 62% of the days that were in error at Birmingham had inversions up to 950 hPa, while none of the days with errors at Shreveport showed inversions in this layer. We did not try to determine why Birmingham had so many more inversions than other locations.

4. DISCUSSION

Based on the 39,818 soundings examined in this study, we find that using the 925-hPa temperature as a direct substitute for 950-hPa temperature in computation of the low elevation Haines Index produces lower values than the original formulation of the Index three times out of four. Interpolation of the 950-hPa temperature based on surface and 925-hPa temperatures has a much lower error rate. Adjusting the thresholds used for the low elevation HI and then using 925-hPa temperatures, a method that has been proposed in the past but is not, to our knowledge, in use anywhere, was intermediate in its error rate. Furthermore, there are distinct spatial patterns in the 925-hPa raw method error rates, while the interpolation method error patterns are weaker and vary more among the seasons.

The use of 00 UTC data may be part of the cause of the error rates and patterns seen in this study. Haines (1988) prescribed use of the low elevation HI primarily to the eastern United States, where 00 UTC is in the evening. In fall and spring, it can be after sunset. Evening formation of inversions and stabilization of the lower atmosphere may lead to the type of situation seen in the Birmingham data, even though midday values of the various methods would agree more closely with the original HI method. Nonetheless, since the original method relies on 00 UTC data and we sought to employ actual sounding data, we limited our analysis to this time.

It is always important to recognize that this type of analysis does not provide any evaluation of how well the HI indicates large or erratic fire risk. Such an analysis requires some measure of fire behavior. This study only considered how well alternate methods of computing the HI simulated the original method.

The results here do show that there is no scientific justification for using 925-hPa raw data in computing the Haines Index. It does not reproduce the original formulation with any degree of reliability. Log-pressure interpolation is much more faithful to the original formulation and is easily done on current calculators and computers.

5. ACKNOWLEDGEMENTS

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6. REFERENCES

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