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Communication

The Haines Index – it's time to revise it or replace it

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Abstract. The Haines Index is used in wildland fire management to evaluate the potential for 'large and/or erratic' fire behaviour. Published in 1988 as the Lower Atmospheric Severity Index, it was widely adopted and has become popular among fire managers, especially in the United States. Meteorologists have questioned its validity, however. This study revisits the original publication to consider the scientific basis of the Index. It then examines subsequent studies of the Index's performance. The original Index formulation is found to be incomplete. Some studies suggest that, nonetheless, there may be some association of the Index with large growth events. Others indicate that the Index can be negatively correlated with growth in some situations. The Index, at present, lacks a scientific basis and the limited studies examining its value are inconclusive. It is unclear whether it would more appropriately be revised or replaced.

Additional keywords: atmospheric stability, fire weather.

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Introduction

In 1988, Haines introduced the Lower Atmospheric Severity Index, which became more widely known to fire managers and meteorologists as the Haines Index (Haines 1988). It was intended to show the atmospheric potential for large or erratic fires. The Index has two components (Table 1): the stability component (A), the temperature difference between two prescribed pressure levels; and the moisture component (B), the dew point depression at a prescribed pressure level. The levels used at any location depend roughly on the surface elevation, as illustrated in Fig. 1. The component values are each converted to integers of 1, 2 or 3 and added to yield the final value from 2 to 6. Fire personnel generally consider a 5 or 6 value indicative of a need to be prepared for atypically high fire activity.

The founding paper for the Index, Haines (1988), presents a preliminary effort and the resulting unrefined Index. Haines said in closing:

'This is *a first effort* at constructing a national fire-weather index based on features of the lower atmosphere … it will *undoubtedly* require further refinement and/or additional components….' (italics added by author). Use of that unrefined form of the Index transforms the first-draft nature to weaknesses in the Index and unscientific application. The present paper revisits those weaknesses and their implications for the validity of the Index. These weaknesses notwithstanding, there are subsequent studies looking at how the Index performed for individual fires or over fire seasons. Whether they show predictive or correlative value in the Index is considered.

Problems with the original paper

Developing the Haines Index required both fire data and atmospheric data. For the fire data, Haines solicited information from wildland fire management units requesting 'their worst fire situations over 20 year.' There is no indication of any specific criteria, any objective standards, or any weather-related criteria for the identification of these situations. Whether, or how, the resulting 74 fires were bad situations because of weather is

Table 1. Pressure levels and threshold values for the Haines Index
Numerical subscripts indicate pressure levels (mb or hPa), T indicates temperature (°C), and T_D indicates dewpoint temperature (°C)

Component	Low variant		Middle variant		High variant		Index value
A (stability)	$T_{950} - T_{850}$	<4	$T_{850} - T_{700}$	<6	$T_{700} - T_{500}$	<18	1
		4–8		6–11		18–22	2
		≥8		≥11		≥22	3
B (dryness)	$(T - T_D)_{850}$	<6	$(T - T_D)_{850}$	<6	$(T - T_D)_{700}$	<15	1
		6–10		6–13		15–21	2
		≥10		≥13		≥21	3

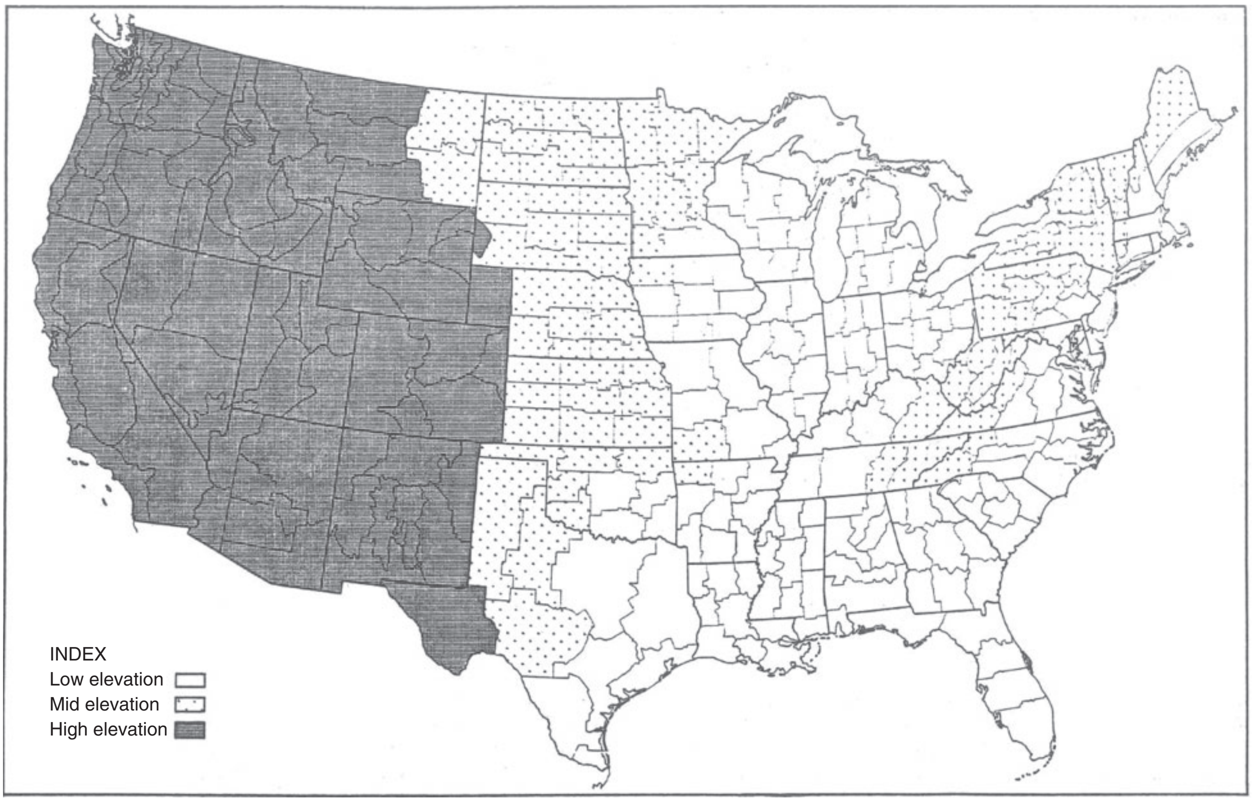

Fig. 1. Map indicating regions where the low-, mid- and high-elevation variants of the Haines Index are used, from Haines (1988).

unknown. They may have been problematic because of management concerns (such as resources available), terrain or unusually complex fuel loads.

Complicating matters, 29 of the 74 fires were in what Haines identified as 'the west', and the meteorological data used for comparison were from 0000 hours UTC on the day each fire was reported. Fires in the western United States often become 'worst fire situations' when they burn for multiple days. Fire behaviour on the day of initial report may be benign or problematic; the fire could be at its worst at any point in its duration. For the 2017 Chetco Bar fire, the 2004 Pot Peak fire or the 2010 Twitchell Canyon fire, to name a few, that duration is as much as 60 days of active burning. Report-day meteorology may not accurately represent the conditions contributing to the identification of the fire as a 'worst fire.' In short, there is no objective or quantitative character to the fires that were used in creating the Index.

With respect to the meteorology of the days chosen, and how it relates to the existing structure of the Index, there are comparable problems. The designated pressure levels and weather metrics used in Haines (1988) are based on the work of Brotak (1977) and Brotak and Reifsnyder (1977). These authors examined stability, wind profiles and dry air advection associated with several fires, and these specific measures are what led Haines to consider the same measures. However, instead of dry air advection at a location, Haines (1988) used only the local moisture deficit in the form of the dew point depression. (Haines suggested that the stability and dryness terms could also be given different weights, but weighed them equally. Whether this is the best choice is an open question.) The difference in moisture measure is not trivial, but it becomes largely irrelevant given what he concluded about wind. Haines (1988) states that the author tried to create a wind component of the Index, but was unable to formulate one that he felt was useful.

> Perhaps a wind term could be included later in an augmented version of the index. However, the disagreement in the literature over the meteorological importance of various wind profiles, coupled with the inconclusive results here, necessitates a delay…

It is unknown how many of the fires used in that study were problematic because of wind, but Haines (1988) left wind out of the Index because all attempts to include it were inconclusive. To further emphasise the importance of this omission, note that Brotak (1977) determined that 92% of the fires in his study were accompanied by unstable air, and 93% were accompanied by dry air (advection), yet 96% had strong surface winds, exceeding 6.7 m s^{-1} (13 knots). The most common correlate is the one not in the Index.

In summary, the fires used for development of the Haines Index were subjectively chosen and their selection was possibly based on behaviour from days not represented by the sounding data examined. Of the three measures from Brotak (1977) that Haines (1988) used as the basis for Index structure, only one was used as Brotak used them – dry air was used in a modified formulation, and wind was completely omitted.

Subsequent analyses

There are three refereed papers, one unrefereed final project report and one informally reviewed technical report that evaluated the Haines Index. All five of these sources are examined here, but the evidentiary weight is arguably greater for the refereed works.

Saltenberger and Barker (1993) (a refereed paper) examined the synoptic events associated with the 1990 Awbrey Hall fire in Oregon. The fire only burned 1 day, from 4 to 5 August, with its greatest spread and most intense behaviour occurring after dark on the 4th, according to those authors. Based on examination of nearby soundings from 1200 hours UTC on 4 August through 0000 hours UTC on 6 August, the authors found the Index had a value of 6 on the afternoon of the 4th, but that dropped to a value of 2 or 3 by the morning of the 5th. Given the description of the fire, there are at most three points for comparison between weather and fire behaviour. Of those three points, two bracket the period of intense fire behaviour and none coincide with the period itself. The Index was 6 before the run, and 2 or 3 after the run. The strictest application of the Index, the 0000 hours UTC value on the start day, would be a 5. The authors' description of the fire environment notes a pre-existing severe drought, extremely dry soundings to as high as 500 mbar, and the presence of a 'fast moving high-level shortwave' at the time of the fire's run. It is neither clear that the Index was high during the run, nor that other factors were not responsible for the run.

In their refereed paper, Werth and Ochoa (1993) applied the Index to their examination of the 1989 Lowman fire in Idaho. This fire burned from 26 July through 3 August 1989, with a final size of 19 000 ha (46 000 acres). Fire activity increased on 28 July, and Werth and Ochoa state:

> Hot temperatures and very low relative humidity developed during the afternoon of 29 July, and spotting pushed the fire 9.3 km toward the northeast.

The fire's progress decreased for the next 3 days, but continued to display 'extreme fire behavior.' They note the fire occurred following a multi-year drought and 2 weeks of high temperatures and low humidities, with extremely dry air at and below 500 mb. The major run, on the 29th, coincided with a Haines Index value of 6, with lower values before and afterwards. However, they note that surface winds nearby were between 3 and 8 m s^{-1}, and the fire burned into a drainage aligned with the wind and filled with dead trees from a blowdown event 3 years prior. This was, furthermore, the day they noted 'spotting pushed the fire 9.3 km towards the northeast.' Any of these factors could have been the reason for the fire spread, regardless of the value of the Haines Index. The spotting alone belies the relevance of the Index, as spotting requires strong winds and the Index does not reflect these. Note that to be true to Haines (1988), the authors should only have examined the Index value (5) on 26 July, the day the fire started.

The same paper examines another fire, Willis Gulch, from the same area but 1 year prior. It, too, was associated with long-term drought. They note a very low snowpack that year presumably contributed further to dry fuels. There was again dry air up to 500 mb, and, as with the Awbrey Hall fire, a short Rossby wave passed over the area at the time of the blow-up. The day of the fire's peak growth, its first day, had a Haines Index value of 5 (moderate), according to the authors. With the collection of contributing factors, it is again not clear that the Haines Index mattered, even if it appears to correlate.

The Goodrick *et al.* (2003) report came out of a project funded by the Joint Fire Science Program. These authors examined the performance of the low-elevation variant of the Index for Florida fires in May and June of 1998 and 1999. They compared the Index with average daily acres burned per fire for the state of Florida (i.e. total acres burned in Florida divided by number of active fires on each day). They concluded that the Index performed well for 1998, but had a negative correlation with acres per fire in 1999. The 1998 correlation was 0.53, but the authors noted that, even with this correlation, the Index's frequency distribution did not correspond well with the frequency distribution of fire sizes. Their closing summary states that:

> the lack of wind information in the Haines index appears to be a serious limitation as it relies solely on convective mixing to transport dry air aloft to the surface and ignores shear induced mixing.

McCaw *et al.*'s (2007) refereed publication compared the Index not to actual fire activity, but to Australia's McArthur Grass Fire Danger Index (GFDI). The area under consideration was south-western Australia. The authors concluded that the Index corresponded so closely with the GFDI that the added value of the Index was limited. They suggested that perhaps studies of fires at the extreme high or low ends of the GFDI range would reveal some added value from the Index. (It is interesting to note that the GFDI includes the effects of wind, whereas the Haines Index does not, yet the authors found strong correspondence.).

In what appears to be an informally refereed technical report, Mills and McCaw (2010) examined a modified version of the Haines Index, which they called the Continuous Haines Index or the C-Haines Index, in great detail. The C-Haines Index is fundamentally different, and their results on that point are not applicable to discussion of the Haines Index in its original form. However, in their motivation of the C-Haines Index they assert that the Haines Index is:

> not configured to identify the most extreme conditions in Australia due to the different temperature lapse and humidity climatology of the two continents [North America and Australia].

Although the differences between two continents may be more extreme, this point emphasises the fact that the Index's utility is highly dependent on locally prevailing conditions. The development in Haines (1988) used only data from 1981 for Winslow, Arizona, and Salem, Illinois, in determining thresholds for values of 1, 2 or 3. Further illustrating Haines' expectation that the Index as presented was a first draft, he states:

> Until a more extensive climatology is developed, this 1-year base will be used as a standard.

Two of the three refereed papers examining the performance of the Index (Saltenberger and Barker 1993; Werth and Ochoa

1993) concluded it worked but listed several independent, contributing factors that may have yielded the same fire behaviour without the conditions captured in the Index. The third refereed paper, McCaw *et al.* (2007) concluded surface conditions correlated so strongly with Index values that there was little gain in using it. The two unrefereed publications (Mills and McCaw 2010; Goodrick *et al.* 2003) cast further doubt on the value of the Index in its existing form.

Conclusions

Although the intent and logic going into the original Index development were sound and the effort employed what was then the state of the science, the resulting Index was unsound, including lacking quantitative fire data. Haines (1988) explicitly states in several places that the Index as presented is preliminary and requires further work. It specifically needs an expanded climatology to refine the thresholds for the two components, and the incorporation of a wind component. In a personal communication, Don Haines stated that he meant the original paper to start an extended effort to develop a fire weather Index. The work was never intended to serve, as initially presented, as the final product. Mr Haines had envisioned an iterative refinement process, with feedback from practitioners. However, his retirement shortly after the publication, and lack of anyone else taking on the project, resulted in the first draft index becoming the final product.

Subsequent studies have sought to evaluate the Index, with results that do not support its use in the original form. Yet it is used operationally across the United States, and elsewhere. Mills and McCaw (2010) produced a modified Index, following the sort of refinement Haines stated was necessary. In its present form, the Haines Index cannot be considered a scientifically designed, complete or verified metric that provides any information on fire behaviour or fire danger.

One could attempt to refine or solidify the existing Index. The moisture term could be replaced with a dry air advection term, and a wind term could be added. The thresholds for all three components could then be tested scientifically to determine the values that best identify days of concern. A quantitative measure of 'day of concern' would be needed, though. Efforts in this direction should consider whether the resulting Index provides information not available from surface-based measures, one of Haines' original concerns. The combination of two or three elements into one index results in a loss of information, and any refinement would do well to consider the points raised by Doswell and Schultz (2006).

If the goal is to create a measure of how conditions above the ground, but not too far above, may influence a fire, perhaps the better course is to replace the Haines Index. Scientific understanding of how fires interact with the atmosphere has advanced since 1988 (e.g. Potter 2012*a*, 2012*b*), as have the data available for both meteorology and fire behaviour. Some of what was accepted in the past is now questioned, such as how instability a few kilometres aloft would actually influence a fire's behaviour. Other important processes like wind shifts triggered by frontal passages or convective downdrafts are coming up more frequently in firefighter training and incident reviews. Haines' (1988) choice of parameters from Brotak's (1977) work could be revisited and critically reassessed. Development should use sound science, be easily explained to and understood by users, include operational feedback, and be field tested for measurable performance.

Conflicts of interest

The author declares that he has no conflict of interest.

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