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Keeping Haines Real—or Really Changing Haines?

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Most incident command teams can handle low- to moderate-intensity fires with few unanticipated problems. However, high-intensity situations, especially the plume-dominated fires that often develop when winds are low and erratic behavior is unexpected, can create dangerous situations even for well-trained, experienced fire crews (Rothermel 1991). Plume-dominated fires have a strong convection column that towers above the fire rather than leaning over before the wind. They differ from wind-driven fires in that the winds are lower and primarily fire induced. Some authors (Byram 1954) have called plume-dominated fires "blowup fires," but that name is now commonly used for any sudden increase in fire activity.

This article updates the uses of the fire severity index called the Haines Index (HI). We discuss the original intended use of HI, its current operational use, some ways that users have modified it, and different aspects of HI that researchers are examining to improve its predictive value.

The Haines Index is a quick and easy tool for summarizing two atmospheric parameters.

Plume-Dominated Fires

Haines (1988) suggested that the growth of plume-dominated fires depends on the moisture content of the air overlying the fires, the environmental lapse rate (temperature difference within a vertical layer of that air), and negative vertical wind shear (Haines 1988). He noted that researchers could use measurements of these atmospheric features to construct a severity index. However, no features could be identified from the usual surface weather measurements; therefore, mathematical descriptors of the features had to be constructed using above-surface observations.

The HI is an indicator of the potential for extreme fire behavior based on two of the three features Haines (1988) described—the dryness and the stability of the atmosphere. HI uses measures of the dryness of air above the fire to calculate the likelihood that an unstable lapse rate will help that air reach the ground. Haines did not include a wind shear term in HI because of disagreement among researchers over the meteorological importance of various wind profiles (see the sidebar on page 42).

Ideally, atmospheric features should be measured in the region just above the mixing layer, where air is mixed by convection. One of the synoptic patterns (atmospheric, weather, or other conditions that exist simultaneously over a broad area) that fire weather meteorologists look for is an upper level ridge of building high pressure, followed by a trough of low pressure. High-pressure areas are characterized by subsiding air that is warmed through adiabatic compression (when expanding air cools and contracting air warms), which occurs because atmospheric pressure decreases with height, whereas the rising air cools and sinking air warms. The air is prevented from reaching the surface because of the cooler, underlying mixing layer. Temperatures within the mixing layer decrease with altitude, but the air just above the mixing layer, having been warmed through the adiabatic process, is often much warmer than the air at the top of the mixing layer. Therefore, a temperature inversion usually separates the mixing layer from the compressed, warm air above (fig. 1).

This situation is ideal for plume-dominated fire development. A breakdown of the upper level ridge, with a cooling of the air aloft and the subsequent instability, often produces the potential for intense plume-dominated fires, especially in the Northwestern United States (Gibson 1996).

Structure of HI

HI ranks the moisture and stability of the lower atmosphere by assigning to each term a value from 1 to 3, as follows:

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Wind Shear and the Haines Index

The Haines Index is an indicator of the potential for extreme fire behavior based on two of the three features Haines (1988) described—the dryness and the stability of the atmosphere. The Haines Index is used to calculate the likelihood that atmospheric instability will bring dry air to the ground, contributing to fire activity.

Another way to bring dry air to a fire is through wind-induced mixing by means of negative vertical wind shear, the third feature described by Haines (1988). However, a wind shear term was not included in the Haines Index because of disagreement among researchers over the meteorological importance of various wind profiles. For example, Byram (1954) listed six types of wind profiles that could be "potential trouble makers," too many to incorporate into a predictive model. Another problem with including wind profiles is the duration of wind events, which can vary from downburst outflows (including those generated by fire), to gust fronts, to nocturnal drainage, to synoptic or geographically preferred areas of low-level jets.

Recently, computer simulations of fire spread have produced interesting results when wind shear is considered (Coen and others 1998; Jenkins 2000). Perhaps this line of research will provide a future, usable solution.

The simplicity inherent in the Haines Index limits its use as an indicator of broad fire potential.

1 = Stable air/Moist air
2 = Moderately unstable air/Moderately dry air
3 = Unstable air/Dry air

When the values of the two terms are added, HI can range from a minimum value of 2 to a maximum value of 6. For example, a moist and stable atmosphere above the fire has an HI value of 2; dry and unstable air has an HI value of 6 (table 1).

HI can be calculated over one of three layers between 950 and 500 millibar, depending on the surface elevation. The layer used should be high enough above the surface, usually just above the mixing layer, to avoid the major diurnal variability of surface temperature extremes and surface-based inversions. Although this lessens the diurnal effects, there is no way to totally negate their influence. For step-by-step procedures about how to calculate HI, see Haines (1988) and Werth and Ochoa (1990).

Using HI

Use HI when you have substantial available fuels, when you have an ongoing fire or are confident of ignition, and when you might expect a plume to build above the fire. A high HI value will indicate the likelihood of rapid fire growth and erratic, extreme fire behavior. A low HI will mean that the smoke column should not extend to a significant height and that there is a low possibility of rapid fire growth and erratic, extreme fire behavior.

Could low moisture and instability in the overlying air contribute to a wind-driven fire? Possibly, but a mechanism to bring the overlying air down to the fire is not obvious. The downdrafts that, on a plume-dominated fire, would carry the air down are conveyed away from the fire by the wind. Fires are complex, turbulent structures; like the proverbial snowflake, no two are exactly alike. Further observations, research, and computer modeling

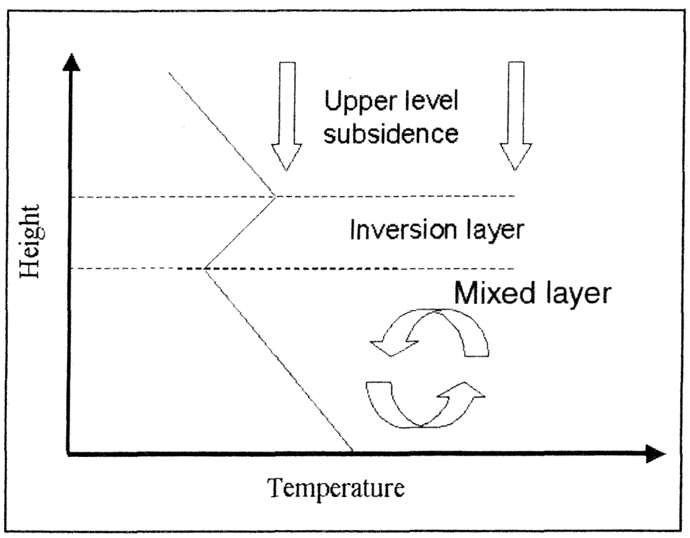

Figure 1—*Temperature profile of an idealized atmosphere that could produce an explosive, plume-dominated fire. Although not the only situation where this might occur, it is an occasion where downdrafts originating in the region above the mixing layer can bring warmer and drier air to an existing fire.*

Table 1—Numeric values of the Haines Index and descriptions of extreme fire risk.

Haines Index	*Potential for rapid fire growth or extreme fire behavior*
2 or 3.............	very low
4..................	low
5..................	moderate
6..................	high

are needed to answer this question (Jenkins 2000). For now, we know that the components of HI can make a major contribution during the growth of plume-dominated fires.

Because there is no wind component in HI, it should not be used to predict the behavior of wind-driven fires. HI can tell you little when strong horizontal winds cause fire-induced winds to shear ahead of the fire. The resulting separation of the fire and the winds generated lessens the possibility of the fire feeding back on its own circulation.

Nevertheless, strong winds can abate during the course of a fire, allowing a vertical smoke column to develop. This happened in May 1980 during the Mack Lake Fire near Mio, MI (Simard and others 1983). Two hours after ignition, strong wind gusts and lowered relative humidity caused a prescribed burn to escape across firelines. The fire burned a total of 24,000 acres (9,700 ha), mostly by the evening of the first day.

During its major run, the Mack Lake Fire spread about 8 miles (13 km) at an average rate of 2 miles per hour (3 km/h). Later, winds slackened, allowing a plume-dominated fire to develop. During such times, an HI value of 5 or 6 could alert firefighters to unexpected fire growth and erratic fire behavior.

HI is not a predictor of wind-controlled fire, ignition potential, fuel conditions, or the number of expected fire days. There are other methods for evaluating these factors, and the wise firefighter will use the corresponding tools.

HI Misuse

Significant changes in fire weather forecasting and, specifically, in forecasting HI occurred during the mid-1990s. Within the National Weather Service and the fire weather program, fire-weather-forecasting responsibilities were spread to more individuals in each office; some offices that had not had fire weather programs in the past began to assume forecasting responsibilities. The new forecasters readily looked to computer-modeling data output for guidance in forecasting HI. Simultaneously, traditional forecast techniques involved analyzing morning sounding data and then predicting changes and deriving an HI forecast. With access to gridded model data, forecasters began to put more emphasis on model calculations to determine projected Haines Indexes. Figure 2 shows a sample of a model-generated HI forecast.

The model output calculated higher HI frequencies of 5 and 6 than expected by experienced fire weather forecasters, numbers that less experienced forecasters were willing to accept because the calculations appeared correct. This led to concerns among more experienced forecasters that users would think the forecasters were

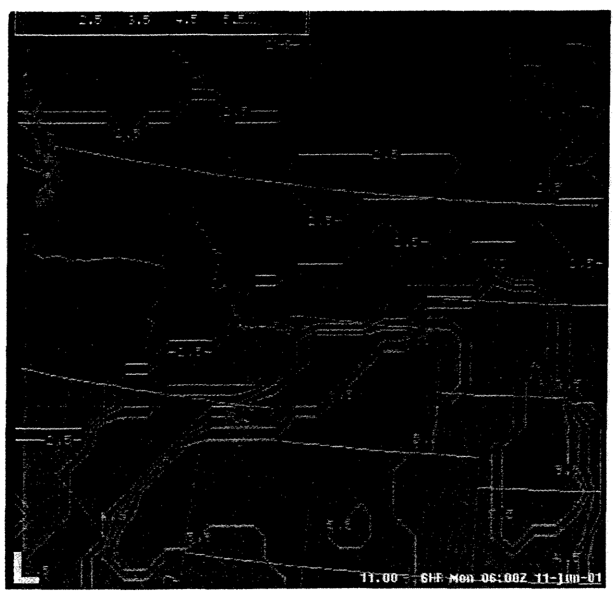

Figure 2—*A sample of a computer model output for the midlevel Haines Index from the 00Z (24-hour clock that is based on midnight at the 0th meridian) on June 11, 2001.*

Future studies will enable us to establish a strong relationship between the physical processes behind the Haines Index and how it is computed.

"crying wolf." In response, some forecasters began rolling factors such as winds, fuel moistures, and fire dangers into calculations that they still called HI. Thus, forecasters-in-training have heard experienced fire weather forecasters comment, "It's not really a 6 Haines day."

Whereas that comment might sometimes be valid, the guidelines for making it are at best nonstandardized and are often nonexistant. The problem illustrates the need to emphasize proper HI use and calculation on the part of both users and forecasters. It is important to understand that HI is used on a national basis and that there is no systematic method for modifying HI values, even though forecasters might develop local methods for doing so. HI is a quick and easy tool for simultaneously summarizing two atmospheric parameters, moisture and stability. Any effort to use HI as a broad fire potential index is constrained by its inherent simplicity.

HI is similar to another meteorological parameter, the Lifted Index, which is used to assess potential fire instability. Like HI, the Lifted Index does not take all levels of the atmosphere into account in assessing the convective potential. Forecasters now use multiple parameters to assess the overall potential indicated in the atmosphere. Methods for modifying HI through more detailed analysis are appropriate, especially where locations are near the dividing line between high and middle elevations. However, changes to HI calculations should be made in a systematic way across the Nation, not office by office.

Examination of computer model soundings can help forecasters tell where calculated HI values do not fully reveal the true atmospheric potential, for example when:

- A strong inversion is present below the lower level used for Haines calculations and the fire will not likely interact with the Haines layer (fig. 3). This is common along the Pacific Coast of the United States.
- The moisture content of the atmosphere dramatically changes just above the Haines moisture level so that the values used by HI do not depict the true nature of the atmosphere (fig. 4).
- The mixing layer of the atmosphere extends through the Haines layer, yielding abnormally high instability values (fig. 5). This is of particular concern in areas using the midlevel HI due to their elevation, but where deep mixed layers may develop during the summer.

Even in these situations, a forecaster would be limited to arbitrarily lowering or raising the HI. For example, a forecaster would not know whether to drop an HI value of 6 to 5 or to 4. The only truly

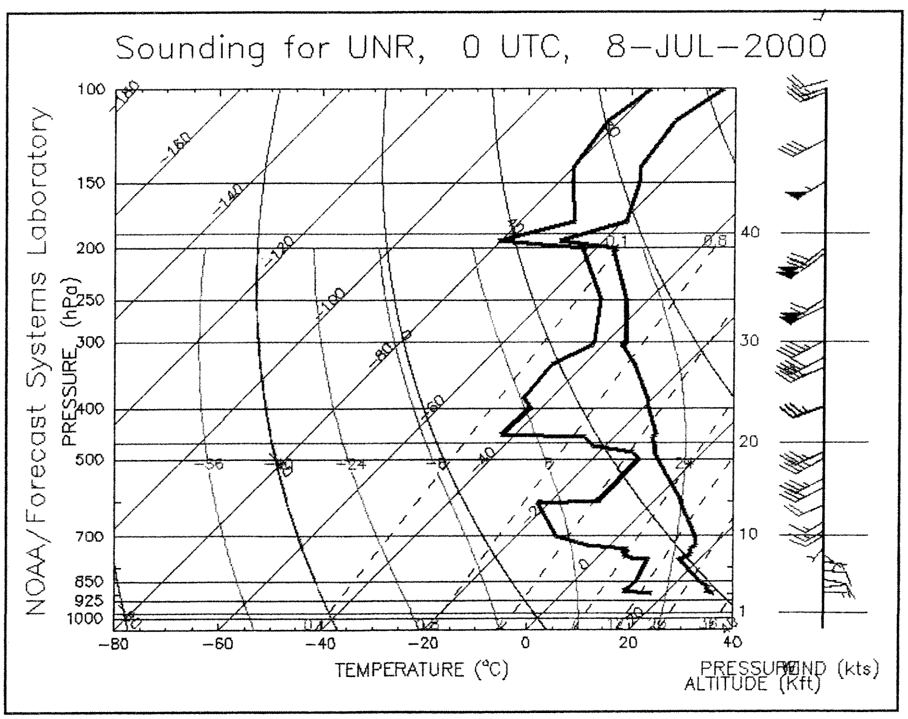

Figure 3—*Upper air sounding from Rapid City, SD, at 00Z (24-hour clock that is based on midnight at the 0th meridian) on July 8, 2000. The low-level inversion would have isolated the surface from the upper air and inhibited the Haines Index layer—700 to 500 millibar—from reaching the ground.*

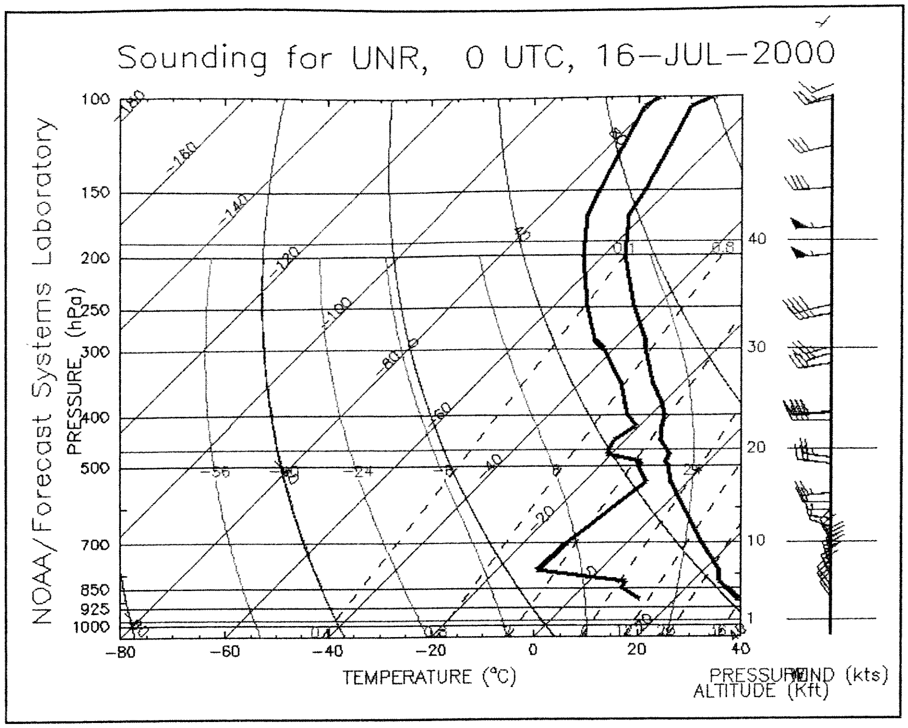

***Figure 4**—Upper air sounding from Rapid City, SD, at 00Z (24-hour clock that is based on midnight at the 0th meridian) on July 16, 2000. The moisture at 700 millibar was not representative of a high-elevation Haines Index layer—700 to 500 millibar.*

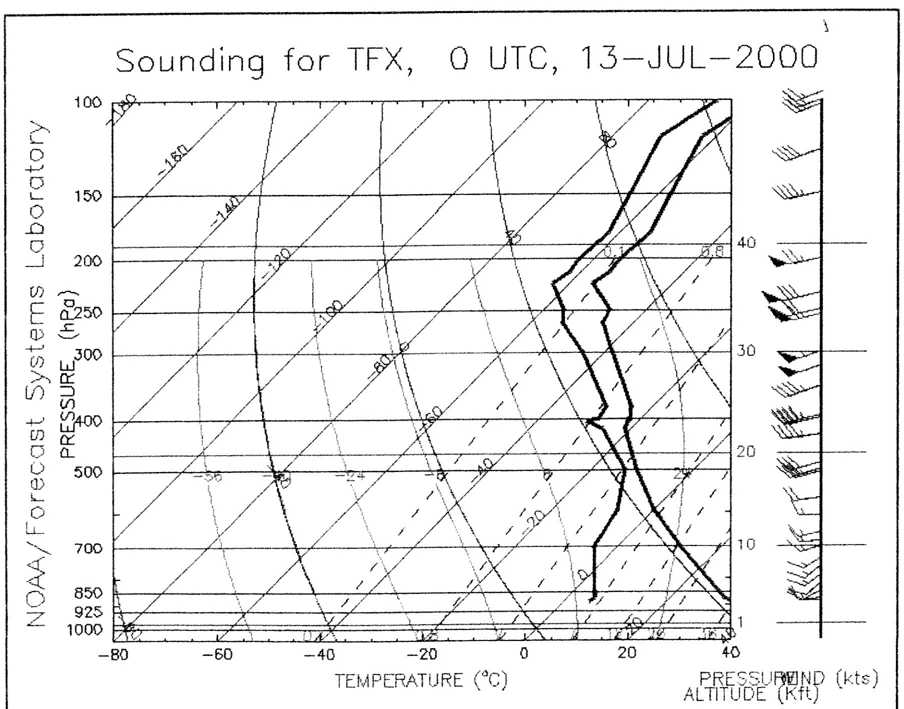

***Figure 5**—Upper air sounding from Great Falls, MT, at 00Z (24-hour clock that is based on midnight at the 0th meridian) on July 13, 2000. The 700 millibar level is deep within the mixing layer, possibly causing a misleadingly high Haines Index for this high-elevation site.*

appropriate practice would be to provide the calculated HI while making note of any atmospheric conditions that might limit or enhance it.

Improving HI

The uses and interpretation of HI are gradually changing, for two primary reasons:

1. There is no "finish line" in science—each question that is answered raises several new questions; and
2. Operational use of HI is pushing it beyond its original purpose and ability.

The climatology used in Haines (1988) relied on two station locations and a single year. At the time, such a climatology required many hours of tabulation and calculation. Today, with greater computer power and data that are more accessible, it is possible to produce a climatology for multiple stations and years. Werth and Werth (1998) did this for 20 stations in the Western United States, covering 5 years at each station. Their analysis showed that the high frequency of HI 5 and 6 values noted in the 1990s was not a product of the computer models—in some areas it is real. Some stations in the high-elevation regions of the West differ significantly from the climatology used in Haines (1988).

With funding from the National Wildfire Coordinating Group and the National Fire Plan, meteorologists at Jackson State University in Jackson, MS, and at the USDA Forest Service's North Central Research Station in East Lansing, MI, are creating an HI climatology for the United States, including Hawaii, Alaska, and Puerto Rico, for 1961 to 1990. When complete, the

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climatology will allow fire weather forecasters across the United States to see how HI behaves in their region during the year and how it compares to other areas of the Nation. The climatology will also provide a starting point for researchers as they try to determine whether or how they should adjust their methods of calculating HI.

The inspiration for HI and the basis for its reliance on stability and moisture came from the observations and experiences of numerous firefighters, researchers, and forecasters over many years (Haines 1988). They enabled Haines to create an index that clearly reflects two important variables in fire weather. Because HI is based on formal and informal observations, it is not explained in terms of physical processes, air motion, or the way that the elevated layer of air used to calculate HI affects a fire on the ground. Understanding these processes would perhaps allow improvements in HI generally, or at least specifically at locations where it is thought to break down.

Piecing Together the Puzzle

We cannot ignite fires under controlled atmospheric conditions to make the needed observations. Instead, we must rely on data from a few fires where all of the relevant measurements were made, and on computer simulations of fire–atmosphere interactions. Using computer models similar to those used for regular weather forecasts and for studying thunderstorms, researchers at Los Alamos National Laboratory, the National Center for Atmospheric Research, the University of Utah, and the North Central Research Station, among others, are trying to refine our understanding of fire weather. Using these models, researchers can specify the stability, wind, and moisture. In turn, the computer simulation provides information on how the atmosphere interacts with an intense fire.

Future studies will enable us to establish a strong relationship between the physical processes behind HI and how it is computed. Whatever the changes, HI will retain its original focus and character—measuring the ability of the atmosphere to turn a low- or moderate-intensity fire into an explosive, dangerous, "blowup" fire under low-wind conditions. This piece of information from HI will fit together with other puzzle pieces, allowing us to calculate the fire risk for a specific situation.

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