3.6 RELATIONSHIP BETWEEN ATMOSPHERIC STABILITY AND AREA BURNED DURING THE 1998 FLORIDA WILDFIRES

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1. INTRODUCTION

During the spring and early summer of 1998, over 2,200 wildfires scorched nearly a half million acres of Florida. Many of these fires rapidly grew to large sizes and threatened and/or damaged private homes (126 were lost). During this period, a strong ridge of high pressure developed over the region and persisted from late April through the first week of July. High temperature records were continuously being set across Florida during the month of June, presenting severe fire weather conditions as these high temperatures contributed to unusually low relative humidity. While these conditions persisted throughout the event, certain days exhibited very dramatic fire growth/activity that is likely tied to atmospheric stability.

This study seeks to examine the relationship between stability and area burned by examining two stability indicators used in wildland fire, the Haines Index (HI) and the Lavdas Atmospheric Dispersion Index (ADI). While the HI is widely used across the United States in fire weather forecasts, the ADI is a smoke management tool that the Florida Division of Forestry has found useful in assessing stability conditions for wildfires.

2. DATA

a) Soundings

The Haines Index (HI) was calculated using soundings for Jacksonville, FL, for May and June of 1998. Jacksonville was selected as it was in better proximity to the majority of acres burned than any of the other upper air observing sites in the region (Figure 1). To best capture stability conditions near the typical mid-afternoon peak in burning conditions, the 00 UTC sounding for the next day was selected (e.g. burning conditions on the afternoon of May 1, 1998 are represented by the 00 UTC sounding from May 2, 1998). For

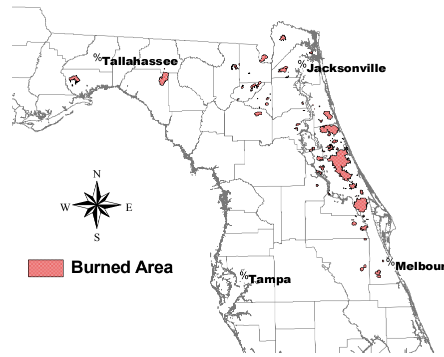

Figure 1: Map of area burned during 1998 wildfires.

Florida a 00 UTC is an early evening sounding (20:00 Eastern Daylight Time).

For the atmospheric dispersion index (ADI), values were collected from the fire weather forecasts produced by the Tampa office of the National Weather Service. In Florida, the fire weather forecasts are produced by 7:30 am local time, which during the summer is prior to the 12 UTC sounding. Thus, observational input for the ADI forecasts is limited to the 00 UTC soundings. The ADI value used in this study represents the value for the forecast zone where the majority of acres burned on that day.

b) Fire Activity Data

Information on daily area burned was collected from the daily reports made by the Florida Division of Forestry districts. This information includes the number of fires and the number of acres burned on each day. Since atmospheric stability is often considered a key factor in large fire growth, the primary fire statistic examined is the area burned per fire per day (Figure 2). A log transform of the area burned data is used in Figure 2 to help reduce the impact of outliers on the visual presentation of the fire data.

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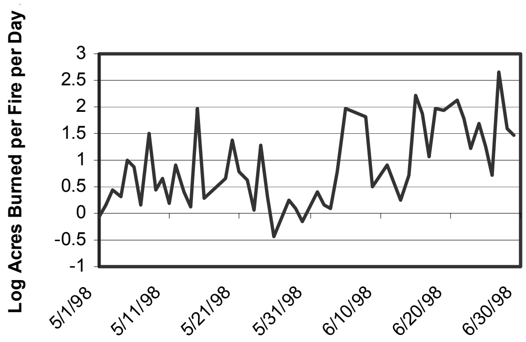

Figure 2: Log of the area burned per fire per day.

3. METHODS

The Haines Index is calculated by simply adding a temperature term to a moisture term (Haines, 1988). The temperature term is the lapse rate, or temperature difference, between two pressure levels in the atmosphere, while the moisture term is the dewpoint depression for the upper pressure level. Both the temperature and moisture terms are classified into 1 of 3 categories. The break points for each category depend upon whether the low, mid or high elevation version of the index is used. For this study the low elevation form of the Haines Index is used which examines temperature and moisture at 950 mb and 850 mb (Table 1). Once the temperature and moisture terms have been classified, the category numbers are added to yield a number between 2 and 6, this number is the Haines Index. Low values of the Haines index indicate a low potential for large fire growth while high values indicate a strong potential for large fire growth.

Table 1: Classification of temperature and moisture terms for the low elevation Haines Index.

Class Value	950 mb T – 850 mb T	850 mb T – 850 mb Td
1	< 4 °C	< 6 °C
2	4 °C to 8 °C	6 °C to 10 °C
3	≥ 8 °C	≥ 10 °C

In contrast to the simple calculations to arrive at the Haines Index, the Atmospheric Dispersion Index (ADI) calculation is much more involved. The inputs for determining the ADI are the stability class (Pasquill-Gifford-Turner classification), mixing height and transport wind speed. The graphical method for determination of the ADI is outlined here (Figure 3) and the reader is referred to the original work of Lavdas (1986) for a more complete description of the index and its calculation.

To determine the ADI, the user first estimates the stability class based on environmental factors such as wind speed, cloud cover and incoming solar radiation. The stability class determines which curve in Figure 3 is used in determining the ADI. The next step is finding the mixing height (in meters) along the x-axis and then finding the Dispersion Index value along the y-axis that corresponds to that combination of stability class and mixing height. This number is then multiplied by the transport wind speed (m s^{-1}) to get the final value for the ADI.

The relationship between the two atmospheric stability indices and area burned by wildfire will be examined through the use rank correlations. Rank correlation was chosen as it removes any underlying assumptions about the distribution of the data. While in our description of the Haines Index we present the index as categorical, it can be viewed as a continuous variable with a range constrained to be between two and six. Correlation coefficients will be considered significant at the 0.01 level, which for 60 samples (degrees of freedom = N-2 or 58) the critical value for a two-tailed test is 0.330 (Kachigan, 1991).

4. RESULTS AND DISCUSSION

Visual analysis of scatter plots showing the relationships between the log of area burned and the ADI and its two components (stability and transport wind term) and the HI and its two components (lapse rate and moisture terms) reveals only weak relationships at best (Figure 4). No HI values of six were observed during the period despite extreme fire conditions. During the period both the lapse rate and moisture terms of the HI surpass the threshold values required to reach class 3, but the conditions never occurred simultaneously.

The ADI and its two terms faired only slightly better. The stability term of the ADI showed the best relationship to fire activity. The ADI itself showed less of a relationship due to the competing stability and transport wind terms.

Rank correlations reveal that only the stability term of the ADI showed a statistically significant relationship to area burned per fire per day (Table 2). Partial correlations were used to account for common effects between the stability term and the transport wind terms of the ADI on area burned. Holding the influence of the transport winds constant slightly improved the stability terms correlation to area burned (R=0.366 versus R=0.353) while holding the stability term's influence constant did not yield a significant correlation for transport winds, but did change the sign of the coefficient (R=0.162 versus R=-0.123). This change makes sense as a fire should grow more under the influence of stronger winds, all else being equal.

The stability term of the ADI is a function of 2 factors: stability class and mixing height. To isolate which of these factors is most important in relation to fire growth partial correlations were conducted between mixing height and the stability term. The rank correlation coefficient of the mixing height with area burned was R=0.469, the best correlation found in this study. The stability component and the mixing height did not show a statistically significant correlation (R=0.291). The partial correlation coefficient between area burned and mixing height with the influence of the stability term held constant resulted in little change (R=0.468). However, the partial correlation coefficient between area burned and ADI stability component with the influence of mixing height held constant showed that the stability component no longer showed a significant relationship to area burned (R=0.256).

This study shows that the tools used by fire weather forecasters may not do an adequate job of assessing the role of stability on wildfire behavior in Florida (as measured by area burned). Neither the HI nor the ADI showed a significant relationship to area burned for one of Florida's worst fire seasons on record. The stability component of the ADI did show a significant relationship to area burned that could largely be attributed to one of its inputs, mixing height.

5. ACKNOWLEDGEMENTS

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6. REFERENCES

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Lavdas, L. G., 1986: An atmospheric dispersion index for prescribed burning. Research Paper SE-256. USDA Forest Service Southeast Experiment Station, Asheville, North Carolina, 33 pp.

Table 2: Correlation coefficients (values above 0.330 are significant at the 0.01 significance level)

Variable	R
ADI	0.179
ADI – Stability	0.353
ADI – Trans. Winds	-0.123
HI	0.075
HI – Lapse Rate	0.181
HI - Moisture	0.142

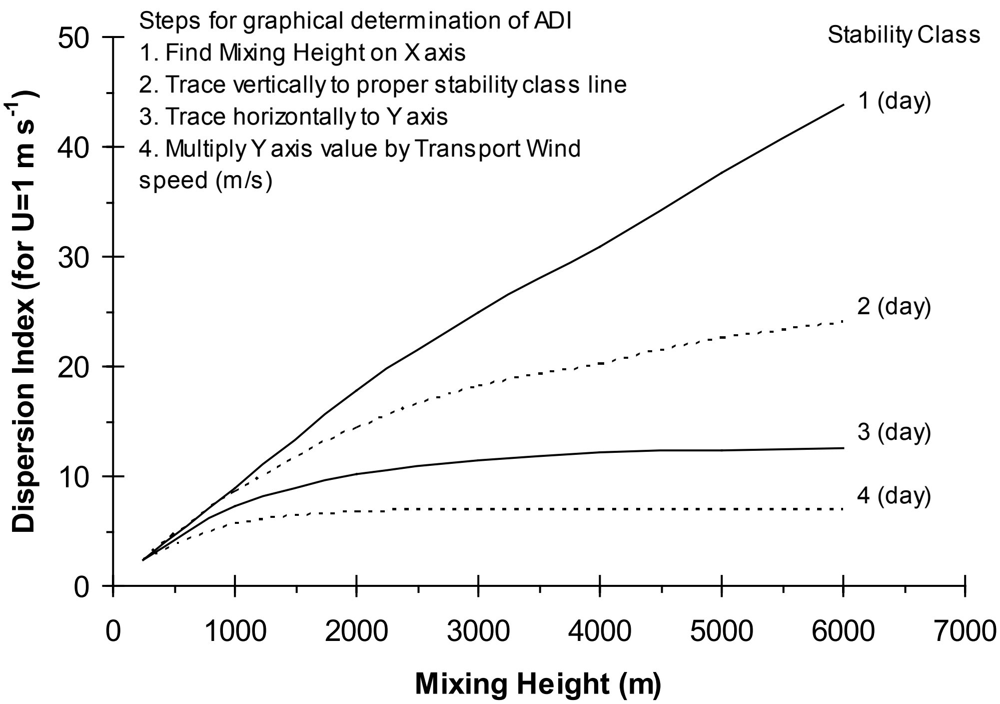

Figure 3: Response of dispersion index to mixing height by stability class for daytime conditions (adapted from Figure 3 of Lavdas, 1986).

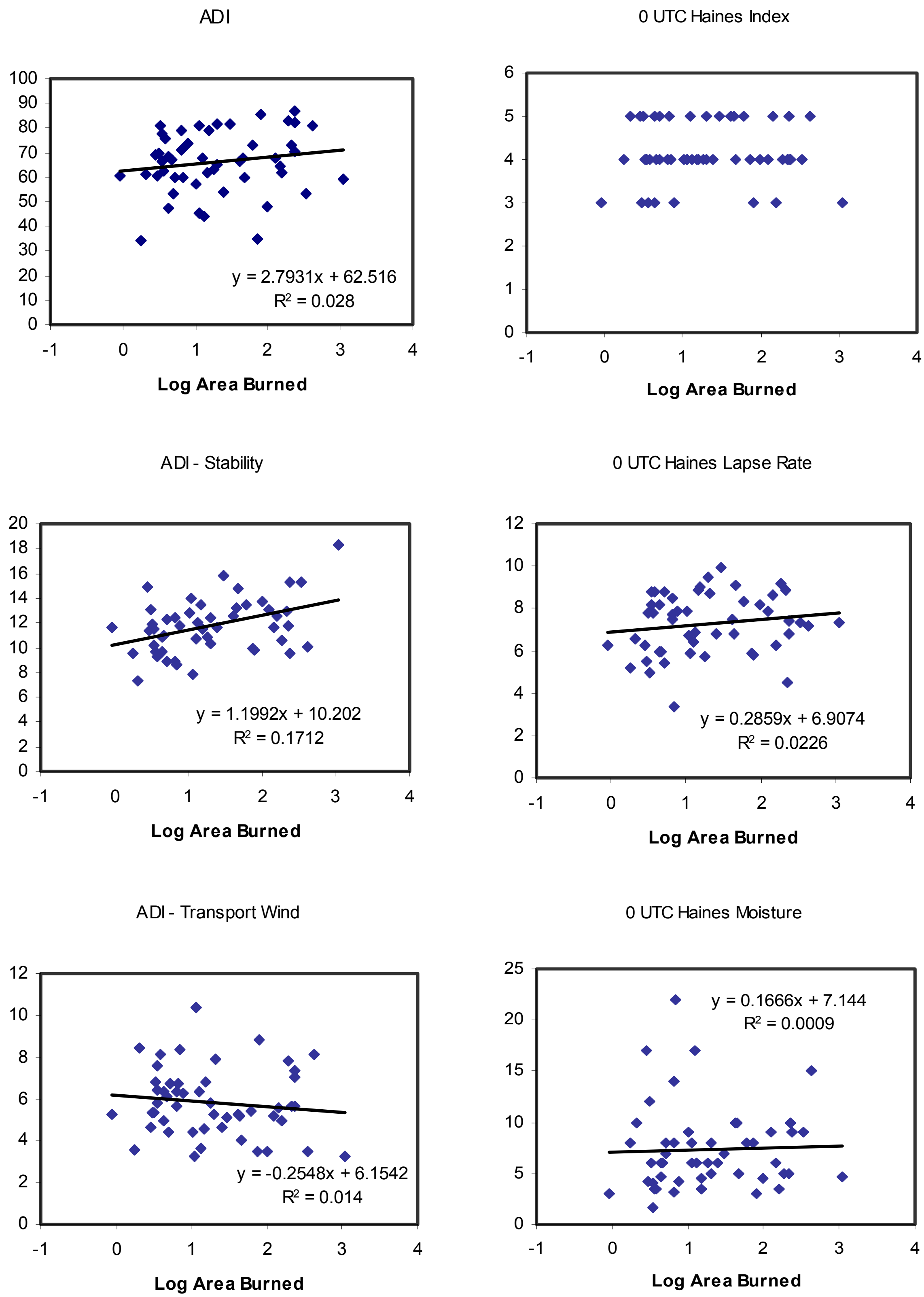

Figure 4: Scatter plots of Log(Area Burned) versus indicators of atmospheric stability