LIGHTNING FIRE OCCURRENCES IN SOUTHEASTERN GEORGIA

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ABSTRACT

The 1532 lightning fires occurring in southeast Georgia from May through August of 1960 through 1968 were most heavily concentrated around the Okefenokee Swamp, probably because of the high incidence of thunderstorms there. Fire occurrence gradually diminished with distance from the swamp. Most lightning fires occurred in the afternoon, between 1600 and 1900 EST. The total number of such fires was greatest in June, and the total number of days with fires was greatest in July. Mean values for buildup index and spread index in the National Fire Danger Rating System were highest on days with no thunderstorms, intermediate on days with lightning fires, and lowest on days with thunderstorms but no lightning fires. Ratings of fire danger could be used as a relative measure of the probability of lightning fire occurrence; that is, on days when thunderstorms are forecast, the higher the fire danger, the greater the probability of lightning fire. However, because of high standard deviations, these fire-danger measures are of limited usefulness in making accurate predictions of lightning fires.

1. INTRODUCTION

Although only 3% of all forest fires in Georgia are caused by lightning, such fires are a major problem in the southeastern section of the state, accounting for 16% of all fires there. In this 16-county area which surrounds the Okefenokee Swamp, 63% of all lightning fires in the state occur; 90% of them in the summer months from May through August. This paper describes: the magnitude of the lightning-fire problem during the summer months in southeast Georgia; how it varies by hour of day, month, and distance from the Okefenokee Swamp; how measures of fire danger reflect the occurrence of such fires in the area; and how forest-land managers can minimize the impact of lightning fire.

2. METHODS

Forest-fire data for the study were obtained from the Georgia Forestry Commission and covered the months of May, June, July, and August of 1960 through 1968. Figure 1 shows the 16-county study area, formerly designated as Georgia Forestry Commission District 8. Vegative cover is primarily slash pine (*Pinus elliottii* Engelm.) and longleaf pine (*Pinus palustris* Mill.), with occasional deciduous hardwood and cypress swamps and cleared agriculture sites. Topography is level to gently rolling, with few points in this part of the state higher than 100 meters msl.

In order to analyze differences in fire danger that may have existed, the 1107 days covered by the study period were classified as those with: (1) lightning fires (LF); (2) thunderstorms but no lightning fire (NF); or (3) no thunderstorms (NT).

To differentiate between days with and without thunderstorms, hourly radar reports prepared by the National Severe Storms Center at Kansas City, MO were analyzed for thunderstorm development. A day was classified as thunderstorm-no-lightning fire (NF) if no lightning fire was reported but a radar cell with a cloud top to at least 7620 m was shown for any hour of the day or night; according to these criteria, there were 485 NF days in the period of the study. There were 385 LF days, on which one or more lightning fires were reported in the study area. The remaining 237 days were classified as NT, having no thunderstorms.

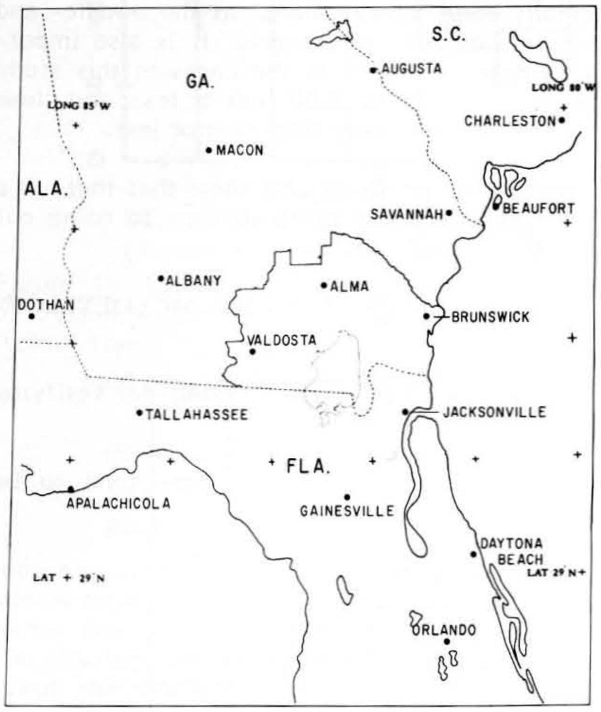

Figure 1. The study area in southeast Georgia is roughly bounded by the cities of Valdosta, Alma, and Brunswick, GA, and Jacksonville, FL. Interior of the study area outlined as dotted area is the Okefenokee Swamp.

Fire-danger data were recorded in accordance with the 8-100-0 Fire Danger System (Keetch, 1954) for 1960 to 1964 and in accordance wtih the National Fire Danger System introduced in 1964 (Nelson, 1964) for 1964 to 1968. The two systems are not directly comparable; hence, it was necessary to translate measures of one into the other to provide a consistent data base from which to make analyses.

The data for the 8-100-0 Fire Danger System were converted to the 1964 National Fire Danger parameters of BUI (buildup index) and SI (spread index). Fuel moisture in the 8-100-0 System was determined by weighing exposed basswood slats. In the 1964 National System, fuel moisture was expressed in terms of relative humidity and temperature and was representative of the moisture content of small fuels such as pine needles. An equation was developed that converted 8-100-0 fuel moisture into the National System fuel moisture (Paul et al., 1972). With the predicted fuel moisture, BUI was calculated directly in the National System. The buildup index was used to represent the accumulated net effect of past weather conditions on intermediate-sized fuel such as branches and small branchwood (up to 1.2 cm in diameter) and duff to a depth of 1.2 to 1.6 cm. Since BUI is increased by low humidity and decreased by rainfall, the index was adjusted daily by an amount corresponding to the drying or wetting conditions that prevailed during the preceding 24 hours. The spread index, which is a relative measure of a potential fire's forward movement, was calculated directly in the National System, using BUI, fuel moisture, and windspeed. Where data were available for more than one location within the study area, simple averages of BUI and SI were taken to represent fire danger in the area for any given day.

3. RESULTS

During the 1107-day period of study, 1532 lightning-caused fires occurred in the area. A geographical plot of these fires is shown in Figure 2. (The few fires within the swamp itself were on higher ground, on small islands.) Figure 3 shows the occurrence of fires by distance from the swamp. The numbers along the positive Y axis show the distance in kilometers from an arbitrarily chosen point within the swamp. The numbers between the lines along an angle to the northwest give the incidence of lightning fires between the two adjacent semicircles. (The number of lightning fires does not total 1532 because the data from the southeast and southwest quadrants were not used in constructing Figure 3.)

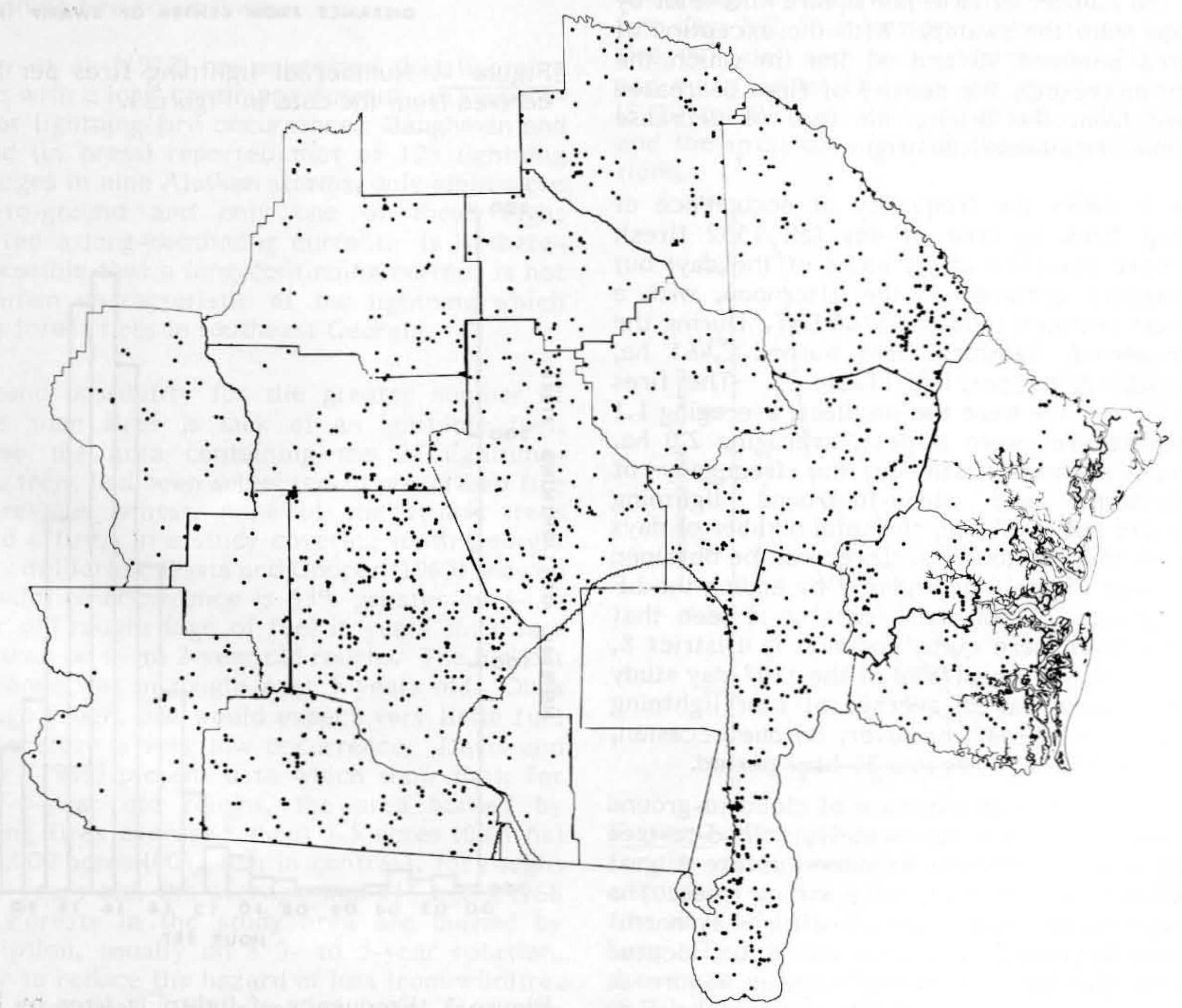

Figure 2. Geographical plot of lightning fires for May-August 1960-1968.

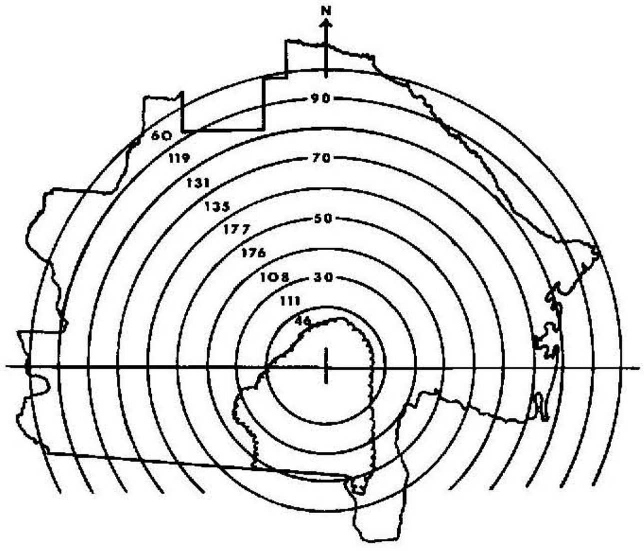

Figure 3. Occurrence of lightning fires by distance from an arbitrarily chosen origin in the Okefenokee Swamp. Distance between rings is 10 km. Numbers between rings to the northwest are number of fires in the northern semicircles.

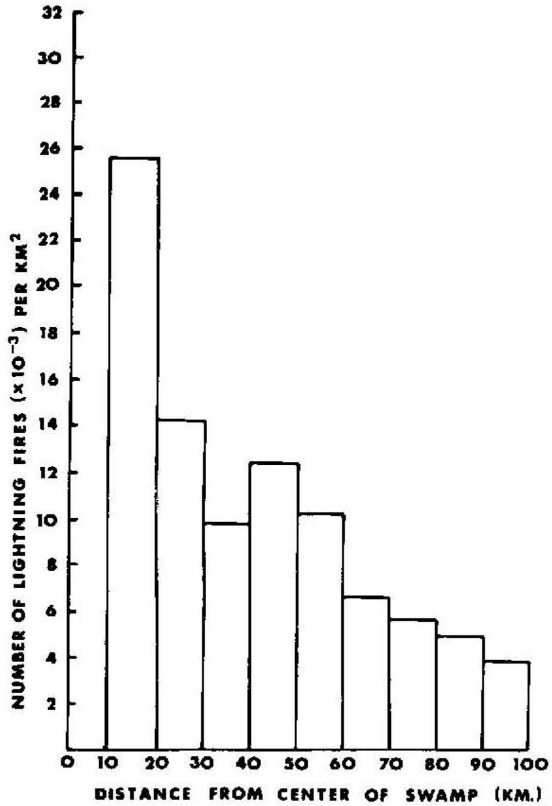

Figure 4. Number of lightning fires per km^2 as derived from the data in Figure 3.

Figure 4, which was developed from Figure 3, shows the number of fires per square kilometer by distance from the swamp. With the exception of the area between 40 and 50 km (in which the density increased), the density of fires decreased outward from the origin, the rate of decrease being most rapid near the origin.

Figure 5 shows the frequency of occurrence of lightning fires by hour of day (all 1532 fires). Fires were observed at all hours of the day; but tne majority occurred in the afternoon, with a maximum between 1600 and 1700 EST. During the 9-year period, lightning fires burned 2,465 ha, averaging 1.6 ha per fire (Table 1). The fires occurring in June were the smallest, averaging 1.1 ha; August fires were largest, averaging 2.0 ha. Although accurate data on the frequency of thunderstorms and cloud-to-ground lightning strikes are not available, the total number of days on which thunderstorms occurred can be obtained from either Figure 6 or Figure 7 by adding the LF and NF days. From these data it is seen that thunderstorms were quite common in District 8, occurring on 870 days (79%) of the 1107-day study period. There was an average of four lightning fires on each LF day; however, on one occasion, there were 32 such fires in a 24-hour period.

In order to obtain an estimate of cloud-to-ground activity, or, more accurately, cloud-to-tree strikes, a small area was examined in late August of 1968 for number of lightning-struck trees. The area was on an 0.8-km stretch of highway northeast of Waycross, GA, and would be located between the 20- and 30-km rings in Figure 3. Trees were counted on each side of the highway to a depth of 0.1 km. This small area was 0.16 km^2 in

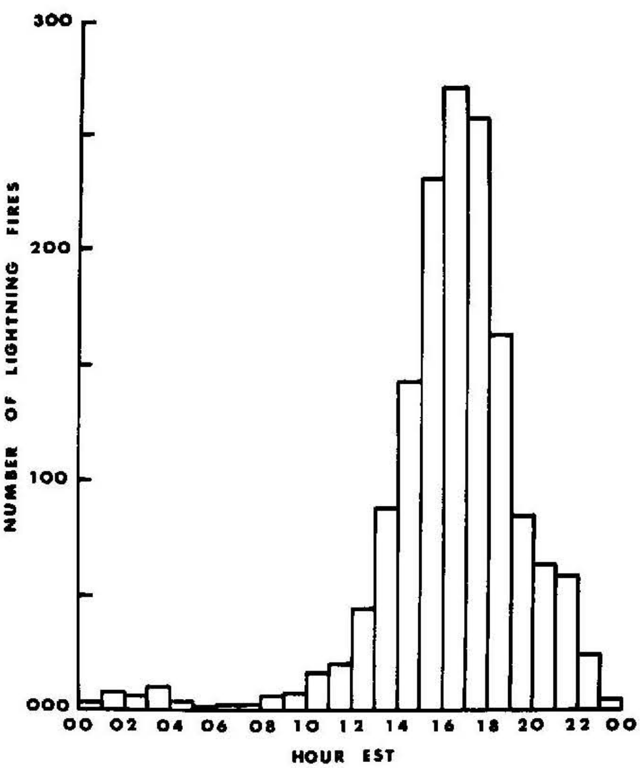

Figure 5. Frequency of lightning fires by hour of day.

TABLE 1

Lightning-caused fire occurrence in the study area by month, with hectares burned for the period 1960 through 1968

Month	Total number of fires	Total hectares burned	Average hectares per fire
May	388	703.9	1.8
June	458	482.9	1.1
July	385	678.7	1.8
August	301	599.8	2.0
All months	1,532	2,465.3	1.6

size. Twenty-seven trees had been struck by lightning in 1968. By converting the "struck-tree values" to "struck trees" per square kilometer (27/0.16 = 155) and lightning fires per square kilometer for the 9-year study period (Figure 4, 0.141 fires/km^2) to a density for a 1-year period (0.141 fires/km^2/9 years = 0.016 lightning fires/km^2/year), it becomes apparent that there were many more strikes than fires. If this small area of struck trees is representative of the study area, then one must conclude that number of lightning strikes is not always the deciding factor in lightning fire occurrence.

Fuquay et al. (1972) has suggested that lightning strikes with a long-continuing current are responsible for lightning fire occurrence. Baughman and Schmid (in press) reported that of 123 lightning discharges in nine Alaskan storms, only eight were cloud-to-ground and only one of these eight exhibited a long-continuing current. It is therefore possible that a long-continuing current is not a common characteristic of the lightning which causes forest fires in southeast Georgia.

A second possibility for the greater number of strikes than fires is lack of an ignitable fuel. Because the area containing the 27 lightning-struck trees had been subjected to prescribed fire the previous winter, none of the struck trees started a fire. In a study covering south Georgia and north Florida, Davis and Cooper (1963) showed that wildfire occurrence is 63% greater on 3- to 5-year old roughs (age of fuel in years since last burn) than on 0- to 2-year old roughs. The highest occurrence was in roughs over 5 years old. On a zero-age rough, one would expect very little fuel and therefore a very low occurrence. Davis and Cooper (1963) present data which show that, for 0- to 5-year old roughs, the area burned by lightning fires averaged about 1.5 acres (0.61 ha) per 10,000 acres (4047 ha); in contrast, for roughs over 5 years old, the average was 415 acres (168 ha). Forests in the study area are burned by prescription, usually on a 3- to 5-year rotation, largely to reduce the hazard of loss from wildfire. If all prescribed fires were excluded from the forest, then one could expect an increase in

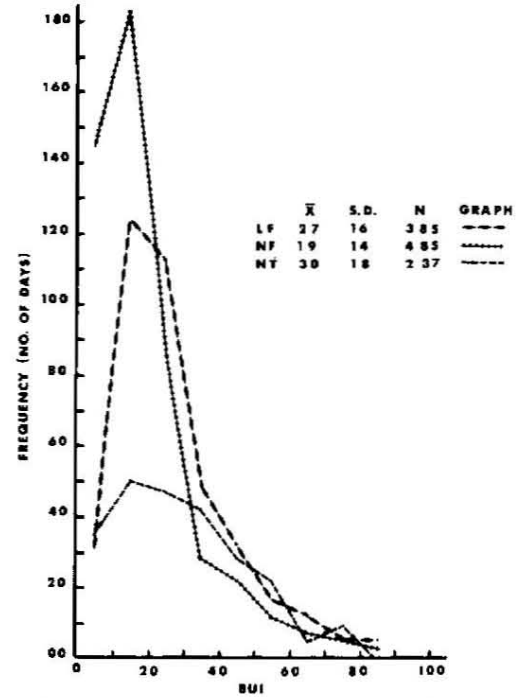

Figure 6. Frequency of occurrence (No. of days) for various levels of BUI during the study period according to day classification -- LF, lightning-fire day; NF, thunderstorm day with no lightning fire; NT, day with no thunderstorm. Also shown are mean values ($\overline{X}$) and the standard deviation (S.D.) for BUI according to the day classification and the total days (N) for the various classifications.

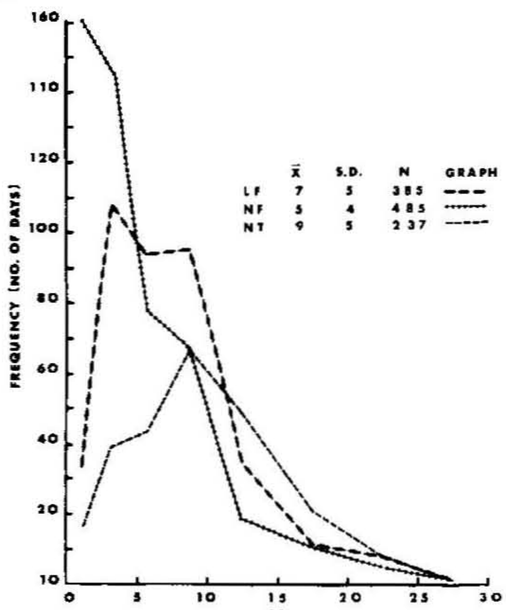

Figure 7. Frequency of occurrence (No. of days) for the various levels of SI during the study period according to day classification -- LF, lightning-fire day; NF, thunderstorm day with no lightning fire; NT, day with no thunderstorm. Also shown are mean values ($\overline{X}$) and the standard deviation (S.D.) for SI according to the day classification and the totals (N) for the various classifications.

lightning fires and more acreage burned as the fuels accumulated.

On LF days the mean BUI (Figure 6, tabular portion) was higher than on NF days, and about the same as for NT days. It was expected that spread index would be related to lightning fire occurrence largely because of the two fuel-moisture components. If lightning strikes produce glowing bark particles which fall on an ignitable fuel bed, then the wind component might also be related to occurrence. Most lightning fires occurred when the spread index (Figure 7) was between 4 and 11. The frequency distribution of both BUI and SI is skewed toward the lower values. The mean BUI and SI (tabular values, Figures 6 and 7) on NF days were less than on LF days, and NT days had the highest BUI and SI. The standard deviations of both BUI and SI are high for all day classifications and consequently limit the usefulness of SI and BUI.

4. CONCLUSIONS

A cursory inspection of the raw data on geographical occurrence of lightning fires shows a maximum density near the edge of the Okefenokee Swamp, followed by a rapid drop as distance from the swamp increased. Analysis, especially Figure 4, verifies this observation.

The most logical and most probable cause of the high incidence of lightning fires in the area is the high occurrence of thunderstorms near the swamp. Most lightning fires did, indeed, occur in the afternoon, the period of greatest thunderstorm formation.

Perhaps occurrence of thunderstorms was high near the swamp because of the existence of a convergence zone in that area. In an earlier paper, Paul et al. (1968) computed the hourly divergence of the average wind field in the vicinity of the swamp for the summer months. The analysis showed a maximum of converging winds in the area of the swamp in the late afternoon. The data were not sufficient to show the precise location of the converging zone, but the existence of these converging winds would be a positive factor in the formation of thunderstorms. The authors also hypothesized the existence of a swamp breeze flowing from the cooler water area of the swamp and interacting with the prevailing wind to form the convergence. These earlier findings would logically fit results of this study, i.e., a maximum zone of fire occurrence around the swamp.

Other possible, though unlikely, explanations are high-level dry thunderstorms or an unusual number of lightning strikes around the edge of the thunderstorm where rainfall is insufficient to extinguish the fire. Although not conclusive, discussions with local residents and Georgia Forestry Commission pilots tend to discount the high-level dry thunderstorm theory. Another more remote possibility is that the soil or vegetation in the area has electrical properties conducive to lightning strikes.

Most of these lightning fires occur in the summer, when the active growth of trees provides an abundance of heat-susceptible young tissue and when commonly low-wind conditions permit heat to rise and produce maximum damage in the crowns; in contrast, most prescribed fires occur in the fall, when trees are dormant and when there is usually sufficient wind to carry the heat away from the crowns. Thus, the potential danger of lightning fires might be expected to be greater than for prescribed fires. However, the actual fire danger rating is approximately the same during the summer and on autumn days when most prescribed burning occurs. Although we maintained only informal records of mortality, they showed that some lightning fires did little damage, especially those burning in mature stands under conditions of low-fire danger.

We conclude that a forest-land manager can minimize the impact of lightning fire by the following actions: (1) maintaining up-to-date maps of the age of rough (in the event that multiple fires had occurred, he could then choose to attack the fire that had the highest potential for damage); (2) using, where possible, prescribed fire to keep the age of rough under 5 years; (3) maintaining current records of thunderstorm occurrence (the location of previous rainfall can be used to adjust and interpret fire danger measured at a central headquarters).

In the future, computerized radar information, supplemented by satellite data, could provide a land manager with detailed rainfall maps. Krueger (1971) describes how radar has been used by fire-weather forecasters and discusses how digital radar data can provide detailed rainfall maps over large areas. The junior author of this paper is researching the use of satellite-infrared and visual data to return an integrated value of fire danger over southeastern Georgia. These developments are promising and, if proven, will be useful to a fire manager.

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THE DEEPENING OF A LOW-LEVEL TROUGH AS INDICATED BY DUST ALOFT IN GOES-1 INFRARED PICTURES

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1. INTRODUCTION

Dust aloft in the plains area of the central United States has been observed on satellite pictures on several occasions.[1, 2, 3] The occurrence of blowing dust is recognized as a problem to agriculture, aviation and other activities. The occurrence of dust as indicated by satellite pictures can also be used as a forecast aid. On 13 March 1977, a low-level trough was moving slowly eastward out of the Rockies. As it moved over the plains it deepened rapidly. As the low-level winds became more southerly and increased in speed along the eastern side of the trough, quantities of dust were indicated by GOES-1 infrared pictures from eastern Texas and Louisiana to Kansas. The shift in low-level winds as indicated by dust aloft in the GOES-1 pictures provided evidence of the rapid deepening of the trough many hours sooner than provided by constant-pressure charts.

2. DISCUSSION

On 10 March 1977, a rather deep low, with a tight pressure gradient and strong surface winds moved out of southeastern Colorado into Kansas. The surface low became virtually stationary over Kansas for about thirty-six hours (from 0000 GMT, 11 March 1977 to about 1200 GMT, 12 March 1977). During this thirty-six hour period, the associated cold front moved rapidly eastward across Oklahoma and Texas. During this time strong winds on the west and south sides of the low picked up quantities of dust, resulting in reports of dust and blowing dust over southeastern Colorado, eastern New Mexico, western Kansas, western Oklahoma and most of Texas. After 1200 GMT, 12 March 1977 the low moved rapidly northeastward over Iowa, southeastern Minnesota and Wisconsin, leaving quantities of dust aloft over the plains area.

By 1200 GMT, March 13, 1977, a new surface trough lay from southeastern Wyoming across eastern Colorado and along the Texas-New Mexico border (Figure 1). This trough was reflected at 850 mb as a shallow short wave (Figure 2), while the only indication of the trough that could be