FIRE TEMPERATURE DYNAMICS IN GRASSLANDS OF THE EASTERN GREAT PLAINS

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Abstract: This study was undertaken to determine the dynamics of temperatures in Iowa grassfires using a field based approach. Five representative grassfires were instrumented and monitored with dataloggers and thermocouple sensor arrays to determine the pre- and postfire thermal characteristics. The burns were conducted in varying terrain and at different times of the year to represent the range of conditions present in Iowa grassland communities. Maximum temperatures occurred at the surface ant at 0.75 meter (29") above the surface, with the cooler fires more likely to have a maxima at the surface and a longer residence time. The maximum fire temperature recorded was 875°C (1606°F). In only one location did the subsurface temperature reach a temperature lethal to plants and seeds. A consistent pattern of short term subsurface temperature decreases were also recorded during every fire. The maximum recorded decrease from ambient temperature was 5°C (9°F). These fires were all prescribed, with environmental conditions within prescription parameters. These measurements provide a picture of aboveground and belowground temperatures and residence times, giving land managers a useful tool to predict the true potential effects on flora and fauna, as well as potential physical effects to soils.

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Daubenmire (1978:128), described the eastern region of the Great Plains as, "...a fire maintained grassland in a forest climate...." Most researchers agree that tallgrass prairie, particularly the eastern region, is maintained by fire (Gleason 1913, Daubenmire 1978:128, Wright and Bailey 1982:100, Pyne 1984:248, Higgins 1986, Ewing and Engle 1988). Historical accounts indicate that humans were responsible for many, if not most, of the fires on the Great Plains (Pyne 1982:84; Wright and Bailey 1982:80, Higgins 1986). However, anthropogenic changes in the fire cycle and fragmentation of the biome itself over the last 200 years make it difficult to determine the full impact of fire in the tallgrass prairie (Wright and Bailey 1982:81, Pyne 1984:248, Higgins 1986). Despite our limited understanding of the impacts of fire, it has become an accepted tool for natural area management.

To determine the role of fire in a particular community, the characteristics of the fires most likely to burn in the area must be studied. The tallgrass region includes a variety of fire-adapted ecosystems, which differ in specific vegetative associations and microclimate, making it difficult to extrapolate fire effects from one system to another.

The issues of temperature and heat transfer during a fire have been the subject of considerable attention in the scientific literature, although there is little emperical data on grassfire temperatures, particularly in the tallgrass region. Measuring changes in temperature and heat flux in the field can be frustrating and misleading. In a laboratory, to some degree, it is possible to regulate the components of fire and obtain accurate measurements; in the field, combinations of variables cause important characteristics of wildfire that cannot be completely duplicated in a laboratory. Variations within a wildfire can be quite large, and the exact location of expected extremes can be difficult to predict. Such variables include soil moisture, soil texture, organic content of soil, fuel load, fuel moisture, fuel depth, slope, slope aspect, fuel type, wind speed, ambient temperature, relative humidity, and numerous other factors.

A grassfire is a surface fire only, generally characterized by burning with high intensity and a fast rate of spread (Pyne 1984:117). Dry grass is a unique fuel which is 100% available; even with a short residence time a fire can burn 100% of the fuel. The small diameter, high surface to volume ratio, and low bulk density make grass quickly responsive to heat transfer. Frandsen (1973), Albini (1980), and Peter (1992) found that fine fuels (diameter < 1 mm) are heated uniformly during the preheating stage, so conduction is not a major contributor to the process.

This lack of a temperature gradient through a piece of fine fuel allows for more complete and faster combustion, and at a lower temperature, producing "flashy" fuel and thermographs. The flashiness is characteristic in grassfires.

In a grassfire, heat is transferred to soil by 3 mechanisms: convection, radiation, and conduction. Radiation and convection provide most of the heating which carries the fire (Peter 1992). Convection occurs in all fires and is a cycle of air movement in which the heat from a fire creates circulation cells which drive dry, hot air in front of the flames. Radiation, also present in all fires, is most effective in a very intense fire. Conduction is dependent upon the surface to volume ratio and the conductivity of the fuel and does not contribute greatly to the dynamics of grassfires (Albini 1980, Peter 1992).

The delay time is the time needed for fuel to be heated up to the ignition point and is critical to the speed of spread of a fire. Fires will move fastest uphill and before a wind because both of these conditions decrease the delay time by decreasing the distance between the flame/heat and the fuel (Pyne 1984:14, Albini 1980). If conditions are good for burning, more heat is transferred to the fuel ahead of the fire than is needed for combustion, so the fire picks up speed and intensity.

Numerous experiments have shown that little of the heat generated by a fire penetrates downwards (Wright and Bailey 1982:11, Pyne 1984:186, Ingersoll 1988, Peter 1992). Even intense fires, such as those in chaparral, have as little as 8% of their total heat flux downwards (Hungerford et al. 1990). Wright and Bailey (1982:11) found that in a grassfire, even with flames greater than 3.7 meters (12 ft) high, temperatures only reach 175°C (347°F) at a depth of 1.5 cm (0.6 in). Marked temperature rises occurred only to a depth of 1 cm (0.25 in). In laboratory fires with a residence time of almost 20 min, the downward heat pulse penetrates less than 100°C (212°F) at only 5 centimeters (2 in).

During any wild or prescribed fire, a temperature gradient develops downwards (Hungerford et al. 1990). The sharpness of the gradient depends on the characteristics of both the soil and the fire. Peter (1992) showed that characteristics such as the amount of convective heat, and the distance of the surface from a radiant heat source, would have a measurable effect on heat penetration downward. Steward et al. (1989) used the intensity and duration of fire as primary parameters for determining depth of heat transfer, and they point out that it is essential to continue to monitor subsurface temperatures for a period after the fire passes because subsurface temperatures often continue to rise even while surface temperatures are decreasing.

Both Peters (1992) and Hungerford et al. (1990) found that the presence of duff will affect downward heat flow. Dry duff acts as a conductor, contributing significant heat to the soil. Moist duff acts as an insulator to prevent a significant amount of heat from penetrating, because heat is used up in the vaporization of the water. If duff, either dry or moist does burn, and is consumed down to the mineral soil, residence time increases.

Wright and Bailey (1982:9-11) discussed maximum temperatures in various grassfires and speculated that the highest temperatures are associated with "...local accumulations of loosely arranged litter and intense winds...." The maximum surface temperature they found was 682°C (1259°F). Average surface temperatures for grassfires was between 102°C and 388°C (215°F and 730°F). Steward et al. (1989) conducted a series of experimental laboratory burns using fine fuels (0.25 cm) which resulted in a heating time of 25.4 seconds and produced a maximum lethal heat penetration of 6.2 cm (2.4 in). When the fuel load was decreased, lethal heat penetration also decreased.

Thermocolor pyrometers have been used to measure surface temperatures during fires (Gibson et al. 1990). These consist of ceramic tiles with dots of temperature-indicating paint on the unglazed side. Using this method, Gibson et al. (1990) found that maximum temperatures in a Kansas tallgrass prairie were 399°C (750°F), with the highest temperatures occurring where there was small woody fuel such as shrubs and small trees. Although such measurements record the highest temperatures reached during a fire, they only provide a single, static surface measurement, and they give no indication of the rate of temperature increase, residence time, or rate of temperature decline.

Several studies have used thermocouples for measuring the aboveground and belowground temperatures during a fire (Wright and Bailey 1982, Sasaki et al. 1987, Ewing and Engle 1988). The major advantages to this method are greater accuracy and a sequential temperature record of a fire event. The resulting range and residence times of the heat at different depths and heights can be compared with other factors for determining cause and effect relationships. When combined with a data input system such as a datalogger, thermocouples can provide a record of many measurements simultaneously, thus it is possible to correlate aboveground temperature dynamics with subsurface measurements. Ewing and Engle (1988) used dataloggers to sample fire temperatures at 2-sec intervals at 15 cm and 30 cm (6 in and 12 in) above the soil surface. They reported surface residence times of 10,400 ± 1900 degree seconds, based on ambient temperatures before and after the fire. Unfortunately, temperature ranges were not given.

Hungerford et al. (1990) presented data from a variety of fires, including two grassfires, 1 in California and 1 in the southern United States. In these fires, surface temperatures ranged from 93°C to 545°C (199°F to 1013°F). Temperatures at the surface did not always correlate with underlying temperatures. The grassfires were the coolest, and heat lethal to most plants was not reached even at 1 cm (< 0.5 in). Hungerford et al. (1990) pointed out that a "hot" grassfire is hot only in terms of temperature range, and the actual heat transferred may be considerably less than cooler fires which have much longer residence times. The study concluded that duration of aboveground heating is a significant factor in soil heating.

The lack of empirical data with which to test these models leads one to question why such data are so scarce. Thermocouples have been used successfully in the field for obtaining temporal and spatial heat profiles, although there are few of these in the current literature on grassfires.

Our study provides temperature data and analysis from 5 grassfires in Iowa. Measurements include the range of temperatures that occur, various heights and depths and their residence times. To measure these parameters, an array of thermocouples was set up in the path of grassfires to obtain a temporal profile of temperatures above and below ground. This methodology was repeated with grassfires in different areas, with different burning conditions, and at different times of the year in order to analyze relationships and patterns common to all the fires. A great many models already exist which predict heat transfer in soils, but none to date includes natural soil features such as live biomass and a natural moisture gradient.

MATERIALS AND METHODS

Temperature

For measuring temperatures during the fires, a standardized thermocouple array consisting of twelve chromel alumel thermocouples was used (Fig. 1). The array was connected to a Campbell 21X Datalogger. Up to 3 datalogger thermocouple arrays were used in each fire. The dataloggers were then buried, and sensor wires were run from the dataloggers to "mast" setups. For each datalogger, sensors were attached to each of 2 2.5-cm x 3.25-m (1-in x 10.5-in), hollow, galvanized steel poles at heights of 3.0 m and 0.75 m (10 ft and 2.5 ft). Each of these poles is referred to as a "mast." Surface sensors were placed at the ground surface. For subsurface sensors, a shovel was used to make a crack sufficiently wide for the sensors to be inserted into the side at the appropriate depths. The crack was then filled with loose soil and tamped down slightly. Grass, litter, and detritus were then arranged over the top to resemble as closely as possible the undisturbed site. Because this operation unavoidably left a small area of flattened fuel and bare ground, the masts were always placed upwind from the datalogger burial site.

The sensor setup was configured to provide a thermograph of a vertical cross-section. Ambient temperatures for each sensor location were determined by taking an average of the first 20 readings in a sensor data series. In this study, "residence time" refers to the length of time the temperatures were at or above 60°C (139°F) (Wright and Bailey 1982:16, Steward et al. 1989). This was to provide data specific to vegetative effects.

Data were stored on cassette tapes and downloaded and converted to Microsoft Excel format. These data were divided into separate datalogger sites labeled A, B, or C. The 2 masts of the sensor setups used for each datalogger were designated "a" and "b." Data were then fully identified by both an uppercase and a lowercase letter. Such that a label of "Ab" referred to mast "b" at datalogger site "A."

Five experimental burns were included in this project: Broken Kettle(a), Broken Kettle(b), Ely, Dudgeon, and Cedar Hills. These burn units are representative of the range of fuel and burn conditions found in Iowa grassland communities.

These 5 units include a wide range of grassland habitats in Iowa, from native prairie to planted game habitat. Burn conditions ranged from extremely poor at Broken Kettle(a), to excellent at Ely. Terrain ranged from the steep topography in the loess hills, to flat areas in east-central Iowa. A more detailed discussion of each burn unit follows.

Broken Kettle(a) Burn Unit

Broken Kettle Grasslands is a 2000-acre preserve owned by The Nature Conservancy and located in the Loess Hills, 11 miles north of Sioux City, Iowa. This burn was conducted on 6 August 1996. The unit was about 30 acres and vegetation consisted primarily of brome (*Bromus* spp.), big bluestem

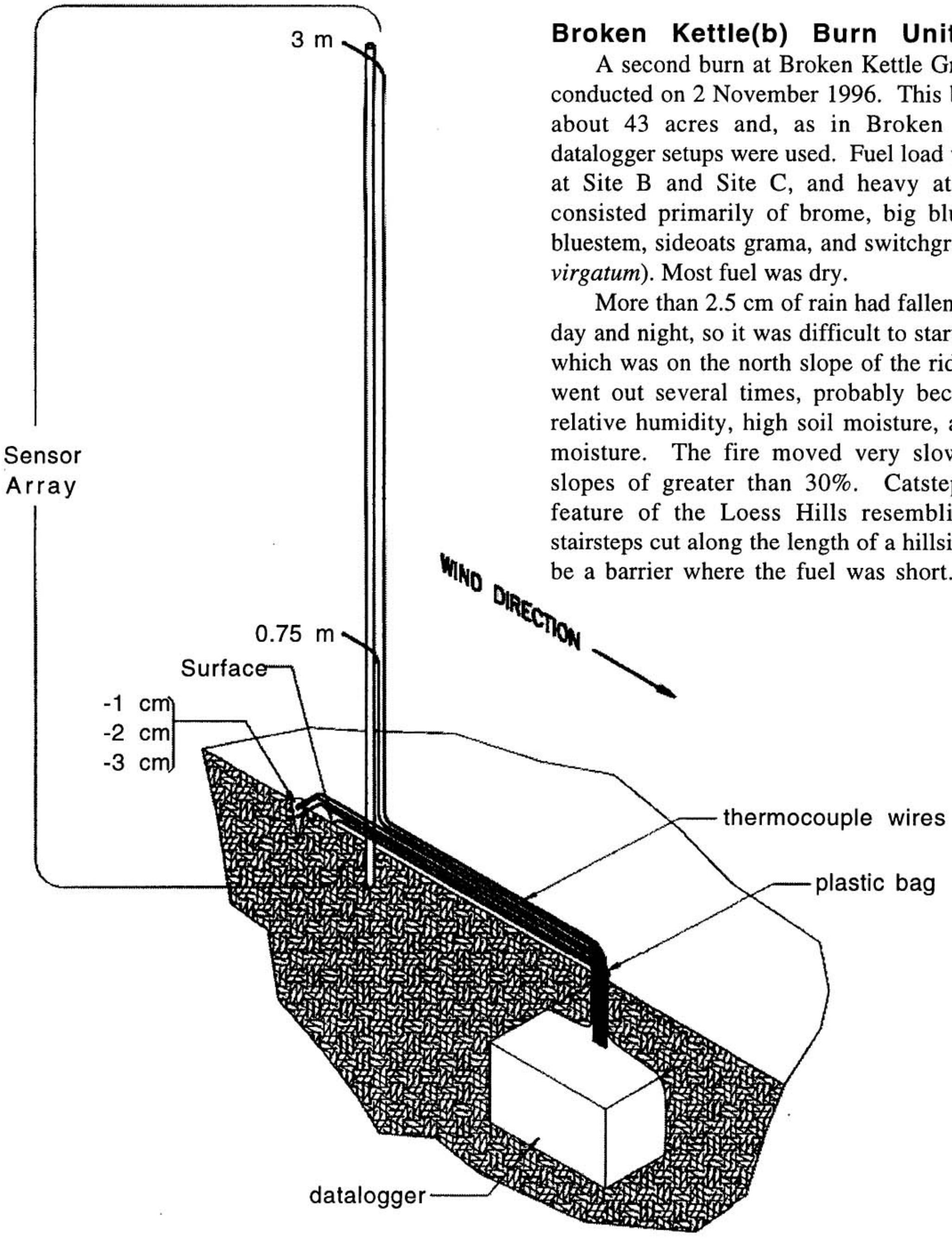

Fig. 1. Instrumentation for temperature measurement in fires.

(Andropogon gerardii), little bluestem (*Andropogon* [*Schizachyrium*] *scoparium*), and sideoats grama (*Bouteloua curti-pendula*). The majority of the fuel was 15-30 cm high, thick, and green. The tallest fuels were dry, but sparse. Forbs were also present, but the sensors were set up in sites dominated by grasses. Three sites (A, B, and C) were set up with two masts and 1 datalogger at each.

Broken Kettle(b) Burn Unit

A second burn at Broken Kettle Grasslands was conducted on 2 November 1996. This burn unit was about 43 acres and, as in Broken Kettle(a), 3 datalogger setups were used. Fuel load was moderate at Site B and Site C, and heavy at Site A. It consisted primarily of brome, big bluestem, little bluestem, sideoats grama, and switchgrass (*Panicum virgatum*). Most fuel was dry.

More than 2.5 cm of rain had fallen the previous day and night, so it was difficult to start the backfire which was on the north slope of the ridge. The fire went out several times, probably because of high relative humidity, high soil moisture, and high fuel moisture. The fire moved very slowly, even up slopes of greater than 30%. Catsteps, a typical feature of the Loess Hills resembling irregular stairsteps cut along the length of a hillside, proved to be a barrier where the fuel was short. In the area around Site A, the fire smoldered past on the surface, leaving most of the approximately 30-cm high green fuel slightly withered, but standing. Flames ranged from about 1.0 cm to a little over 1.0 m high.

Ely Burn Unit

This 20-acre unit, located in northern Johnson County, Iowa, about 1.5 km south of Ely, is owned by the U. S. Army Corps of Engineers. It was burned on 2 April 1997. Vegetation consisted of mixed brome, Indian grass (*Sorghastrum nutans*), and switchgrass with a variety of forbs. Fuel depth was 0.5-1.5 m, and fuel load was fairly uniform. One datalogger setup was used. This fire burned fast and hot, although the head fire which burned through the sensors had only about 12 m (40 ft) to pick up intensity before reaching them. Flames near the sensors were about 2-3 meters (6-10 ft) long, whereas in other areas they reached 6-7 m (20-23 ft).

Dudgeon Lakes Recreation Area Burn Unit

Dudgeon Recreation Area is managed by the Iowa Department of Natural Resources, and is located in northern Benton County, about 3 km north of Vinton. The area for this burn was a rectangular field of about 15 acres of sandy floodplain. The vegetation consisted primarily of switchgrass, with some dropseed (*Sporabalus* spp.); few forbs were observed. This field was surrounded by deciduous forest on all sides. Two arrays were set up, in the approximate center of the field. Most of the fuel was dry.

Cedar Hills Burn Unit

Cedar Hills Sand Prairie is a 60-acre tract of reconstructed and restored tallgrass prairie owned and managed by The Nature Conservancy. It is located in Black Hawk County, Iowa, about 16 km northwest of Cedar Falls. The burn unit was about 8 acres along the eastern border of the preserve. Vegetation consisted of a variety of forbs and grasses, but the sensors were both set in areas dominated by little bluestem. Two datalogger setups were used, both set up in the south central region of the burn area.

RESULTS

The 5 fires reflected a wide range of conditions and they ranged from fast and hot, to slow and cool. The Ely and Dudgeon fires were very hot, very intense, and burned quickly; both locations had ideal fuel (tall, thick, and dry). The Broken Kettle(b) site also contained high fuel loads and burned hot, but because there was little wind and ambient temperatures were low, the rate of progress of the fire was relatively slow. The Cedar Hills fire was cooler, slower, and generally a less intense fire. Broken Kettle(a) was by far the coolest fire.

The data collected in this study are presented in the form of thermographs. These are line graphs which allow the temperature dynamics of the fire to be observed.

Broken Kettle(a)

The thermographs from the site at the Broken Kettle(a) burn are divided into: a) a 4-min period when the effects of the approaching fire were first apparent and b) a 7-min period when the fire was actively burning through the sensors (Fig. 2). The break in the graph represents 13 min of little change before the fire burned through the sensors. The readings from 0.75 m (2.5 ft) and 3 m (10 ft) reflect the increase of temperature variation almost 20 min before the fire actually reached the sensors. The fire approached this sensor from the downhill side, and was also burning below the sensors on the southwest, west, and northwest sides of the slope before it reached the sensors. As indicated by the thermographs, the soil at all depths began to heat up before the fire was very close. At Site A, the fire burned over the sensors which were on the surface underneath some green fuel which did not burn. These sensors recorded the coolest surface temperature of any of the fires. By contrast, Site C from the same fire had a southwestern aspect, was on the shoulder of the ridge, and had taller, drier, fuel. Fuel consumption in this area was 100%.

Broken Kettle(b)

There are only 4 complete thermographs from the Broken Kettle(b) burn. Some patterns were characteristic of the time of year. For example, aboveground locations were cooler than the subsurface locations both before and after the fire. Another seasonal pattern was indicated by the speed with which aboveground sensors cooled off, particularly at the headfire locations which did not burn until almost sunset when the ambient temperature was dropping rapidly.

Ely

The B mast at Ely showed the sharpest drop in subsurface temperature of all the fires: 5.62°C (10.12°F) in 3 seconds at -1 cm.

Dudgeon

The Dudgeon fire burned very hot and fast with flames of 3-6 m (10-20 ft) long, a big column of smoke, and weak fire whirls. Data from this fire include the highest temperatures found in this study. The sensors had been fastened to the masts with masking tape wrapped about 1 cm thick (Fig. 3). After the fire, 1 of the 3-meter (10-ft) sensors was laying on the ground about 1.5 m (5 ft) from the mast and there was no sign of any tape. The slow cooling off period is shown on the thermograph,

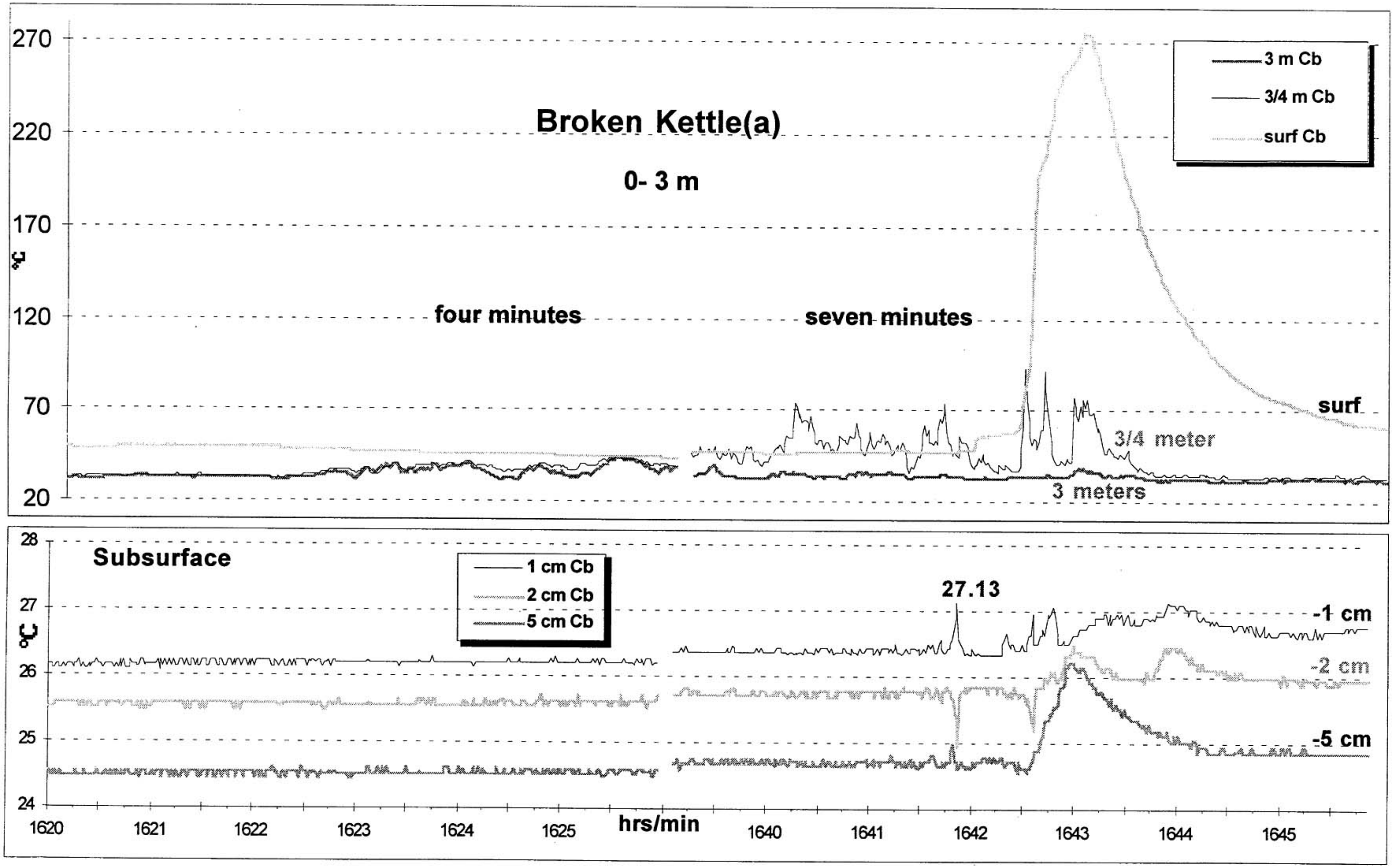

Fig. 2. Thermograph from Broken Kettle(a).

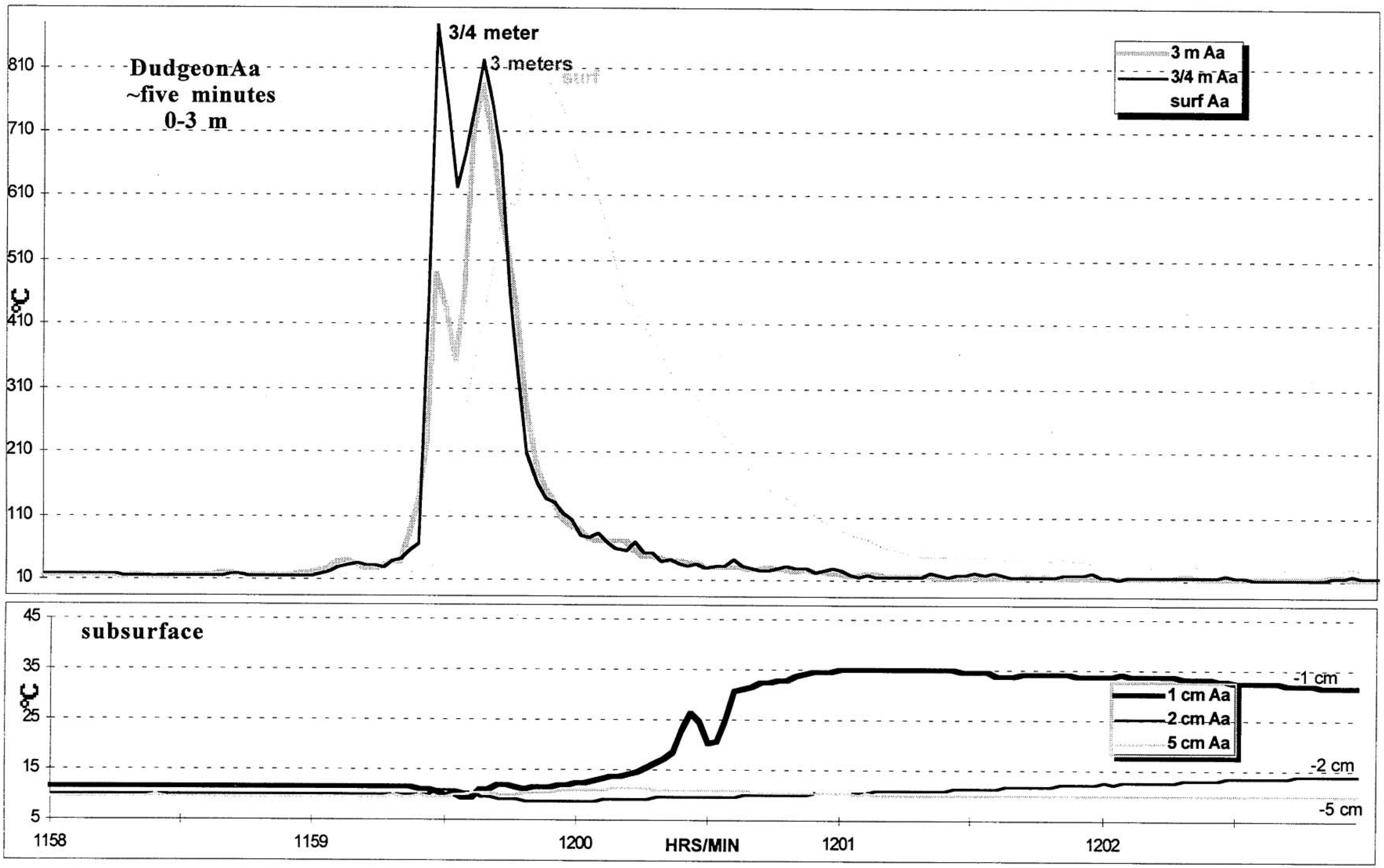

Fig. 3. Thermograph from Dudgeon

although it is not clear at what point the sensor fell. The reading for 3 m (10 ft) at this site for the Dudgeon fire was not included in the correlations.

Comparisons Between Fires

As a measure of how hot each fire was, the maximum temperatures from the sites at each burn unit were averaged. These temperatures ranged from an average maximum temperature of 787°C (1449°F) at Dudgeon to 109°C (228°F) at Broken Kettle(a). Peak temperatures recorded ranged from 875°C (1601°F) at the Dudgeon fire, to 276°C (529°F) at Broken Kettle(a) (Fig. 2 and Fig. 3). Maximum temperatures occurred at the soil surface at 12 of 18 sites; and at 0.75 m (2.5 ft) at 5 of 18 sites In the hottest fire, Dudgeon, maximum temperatures all occurred at 0.75 meters (2.5 ft). The second hottest fire, Ely, had 1 of the 2 maxima at 0.75 m (2.5 ft), and 1 at -1 cm. However, the -1 cm sensor was dislodged before the fire, and was not used in these correlations. Lethal heat occurred at the surface 90% of the time; at -1 cm 9%; at -2 cm 5%; and not at all at -5 cm. For the coolest fires, Cedar Hills and Broken Kettle(a), maximum temperatures were all at the surface (Fig. 4).

At every surface location in every fire except the Broken Kettle(a) fire 100°C (212°F) was reached. In this fire, 100°C (212°F) was only reached by 2 of the 6 surface sensors, both at Site C.

In all cases except for the Broken Kettle(a), the dry/green fuel ratio was high, and the time from ambient temperature to maximum was short. In the Broken Kettle(a) fire, maximum time from ambient temperature to maximum temperature at the surface was 1377 sec, an increase of only 0.04°C/sec (0.072°F/sec). By contrast, among all the other fires, the longest time from ambient to maximum temperatures at the surface was 188 seconds. The shortest time to go from ambient to maximum at the surface was 60 sec. This was found at 3 locations for an average temperature increase of 437°C (786.6). The fastest rates of increase were at 0.75 m (2.5 ft) at 20°C/sec and 29°C/sec (36°F/sec and 52°F/sec), both at Dudgeon. The fastest surface rate of increase was 8°C/sec (14°F/sec), at both Dudgeon and Cedar Hills. With 2 exceptions, the maximum temperature at –5 cm (2 in) occurred at least 16 min after the surface had reached its maximum.

DISCUSSION AND INTERPRETATION

Fire Specific Observations

Broken Kettle(a).—The extended preheating period may be a feature of slow burns, particularly on a hill or with a slight wind, and it may help explain why such green fuel was able to carry a fire at all.

Broken Kettle(b)—. Complications during this fourth burn (Broken Kettle, 2 November 1996) made it speculative to try to assign a specific sensor to a specific channel for some of the data. It was, however, possible to determine from the shape of the thermographs which sensors were subsurface or aboveground. Additionally, 3 of the sensors at Site B malfunctioned and produced no usable data, 2 of these were aboveground, and 1 was below. The lack of wind allowed the fire to move fairly slowly despite good fuel, good burning conditions, and slopes in excess of 35%. This caused almost 100% fuel consumption over the entire burn unit.

Ely—. The Ely fire includes data from only 1 datalogger setup because onsite researcher strained a calf muscle during the setup and could do no more.

Dudgeon—. At Site Bb, the tape holding the 3-m (10-ft) sensor was burned away completely. The maximum reading for this sensor was 661°C (1222°F). The 0.75-m (2.5-ft) sensor registered a high temperature of 764°C (1407°F), yet the tape was intact. The residence time at the 0.75-m (2.5-ft) sensor was 184 sec, although the other 3-m (10-ft) sensors measured a residence time of 50 sec or less. There is no obvious explanation for why the tape only burned off the 3-m (10-ft) sensor.

Cedar Hills—. This fire was much cooler and slower than the others [except for Broken Kettle (a)]. Vegetation varied substantially, and it was difficult to find 2 areas with similar fuel.

Temperature

Of the 3 aboveground sensors, the surface sensors were usually the last to warm up and the last to cool down. Typically, aboveground sensors heated up sooner when they were higher above the ground. While placing the subsurface sensors, disturbance to fuel was minimized. It was, however, impossible to replace duff, detritus, and litter in the exact manner in which it had been before being disturbed. This would have an effect on heat transfer to the soil, possibly affecting subsurface sensor readings.

With the exception of 2 of the setups from Broken Kettle(a), the thermographs clearly illustrate the characteristic flashy fuel of a grassfire (Albini 1980, Wright and Bailey 1982:9; Pyne 1984:115-116). Aboveground sensors recorded the change from ambient to maximum temperatures in as short a time as 60 sec. Also characteristic and well illustrated by the thermographs is a short residence time, as the fuels are incinerated quickly. When surface residence

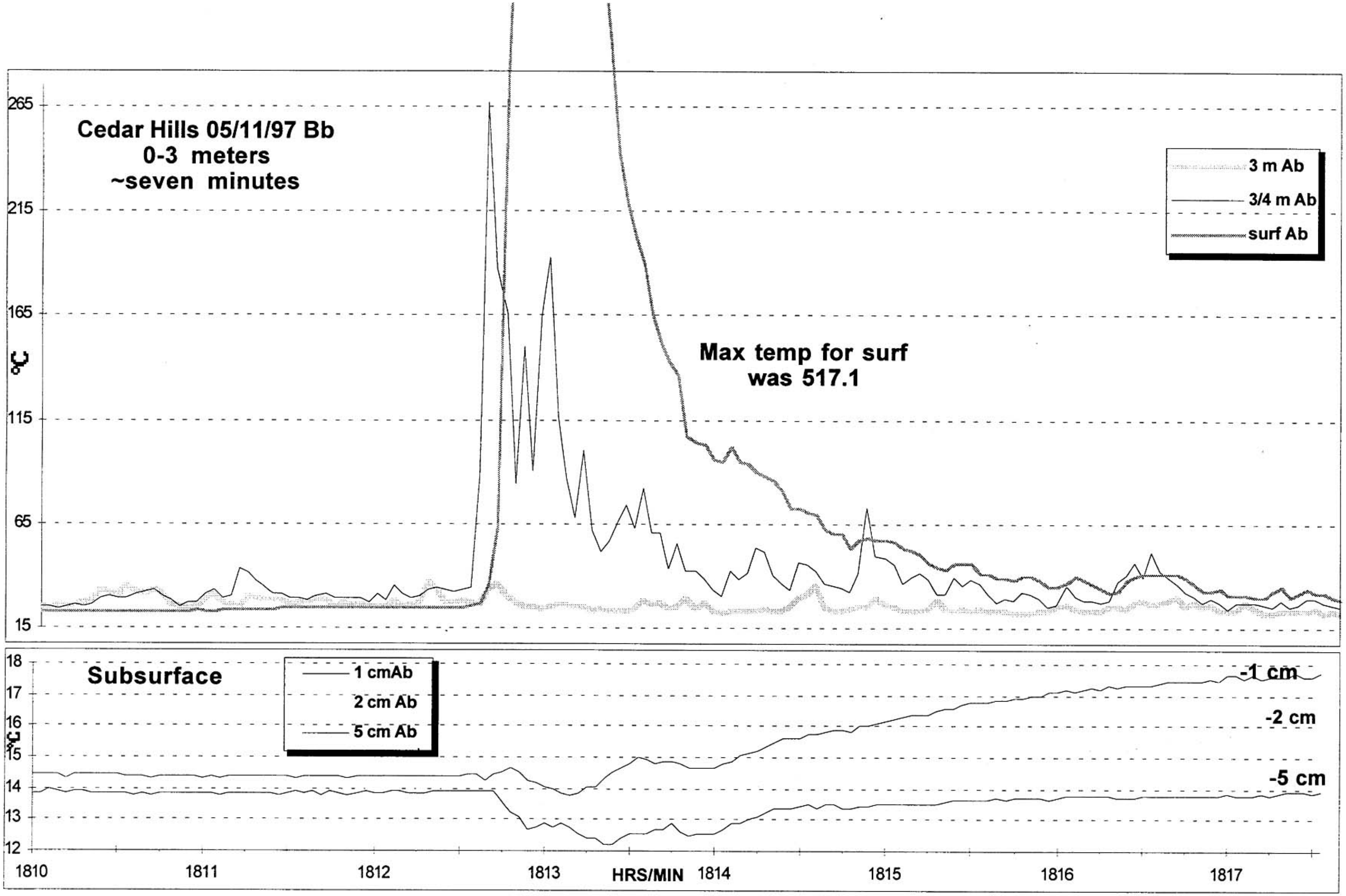

Fig. 4. Thermograph from Cedar Hills

times are graphed with maximum temperatures, there appears to be an inverse relationship, with longer residence times paired with hotter fires.

Wright and Bailey's (1982:9) discussion sets the average surface temperature for grassland fires between 102°C and 388°C (216°F and 730°F), with a maximum measured temperature of 682°C (1,259°F). The average of Dudgeon, Ely, Cedar Hills, and Broken Kettle(a) fires was 403°C (757°F). The only reason the fire burned through all the sensors during the Broken Kettle(a) fire was because it was relit close to the sensors, so it is questionable whether these data should be included as data from a typical burn. Excluding the Broken Kettle(a) fire, the average surface temperature was 502°C (935°F). The maximum temperature recorded in this series of fires was 875°C (1,606°F). Since the fires used in this study were not extraordinary, it further suggests the need for more of the type of data this study provided.

An important aspect of this study was an examination of the depth of lethal heat penetration. A low estimate for this was 60°C (140°F), and was found to have occurred in only 3 instances, none of which was deeper than 2 cm. This penetration is significantly less than was found by Steward et al. (1989), despite longer heating time. In the Ely fire, heating time was 141 seconds and lethal heat penetrated to -2 cm (< 1 in). However, Steward et al. (1989) recorded a heating time of only 25.4 sec for lethal heat to reach 6.2 cm (2.5 in). In both cases, sand was a major component of the soil, but a significant difference was moisture. Steward et al. (1989) did not include moisture as a parameter in their experiments, while soil moisture at the Ely location was 21.5%, by weight. Another factor which may have contributed to this difference is the higher density of fuel used by Steward et al. (1989); they used wooden dowels which, although they were comparable in diameter to grass stems, were more dense and not comparable to grass leaves.

Our study found much shorter surface residence times than Ewing and Engle (1988). Although Ewing and Engle used ambient temperatures to determine residence time and we used 60°C (140°F), even multiplying residence times found here by 100, residence times differ by more than 1 hr. This provides further evidence of the variability of grassfires.

The lack of a significant correlation between surface and subsurface temperatures may be due to the presence of fuel at the surface which provides an immediate and extreme source of heat. Because dry grass burns so quickly, there is little time for subsurface soil moisture to vaporize, affecting maximum temperatures occurring during flaming combustion. The high maxima may reflect a correlation between relative humidity and soil moisture. At greater heights, fuel is thinner, and most of the heat results in the burning of flammable gasses volitilized from fuel lower down. It is possible that ambient air mixes with these flammable gasses to a greater degree than it can mix with the solid fuel at the surface.

CONCLUSIONS

This study demonstrates a viable method for obtaining field-based temperature data from prescribed grassfires. Data obtained from this study illustrate thermal dynamics characteristic of prescribed grassfires. In particular, it appears that for grassfires in Iowa :

1) Maximum temperatures as presented in the current literature are 200°C lower than those recorded in this study. The 875°C maximum recorded at the Dudgeon fire indicates that, in general, maximum temperatures for grassland fires are much greater than previously thought. The Dudgeon fire was not an unusual fire, and burning conditions were not ideal, so it is likely that temperatures in many grassfires exceed the maxima recorded in this study.
2) With a wide range of burning conditions, prescription fires will do little damage to the biomass located in the top 5 cm of soil. At the surface, however, sufficient heat generally occurs to damage or kill most flora and fauna.
3) Soil temperature will decrease temporarily at some point during a fire. This occurred in 95% of the samples.
4) More field data are needed to encompass the variability inherent in wild and prescribed fires. An increase in the number of sensors both above and below the surface, including on top of and beneath duff layers would also be helpful in determining temperature patterns.
5) Data from a wider range of grassfires are needed by land managers to make more informed decisions in determining when to burn, where to burn, and under what conditions to burn.

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