J1G.5 MEASUREMENT OF THE TIME-TEMPERATURE AND EMISSIVITY HISTORY OF THE BURN SCAR FOR REMOTE SENSING APPLICATIONS

Robert Kremens *, Jason Faulring
Rochester Institute of Technology, Rochester, New York
Colin C. Hardy
USDA Rocky Mountain Research Station, Missoula, Montana

1. INTRODUCTION

Wildland fire can drastically alter both the physical and biological characteristics of the forest. For remote sensing applications, it is desirable to know the emissivity, reflectance and temperature of the forest floor both before and after passage of the fire front in order to correctly interpret images obtained from airborne and orbital assets.
.

We have measured the surface temperature and infrared emissivity of the forest floor as a function of time after the passage of the flaming fire front. Many measurements of surface temperatures during a fire have been made to study the ecological effects of a fire (Beadle (1940), Daubenmire (1968), Molina (2001)) but none have concentrated on the physical/optical properties of the burn area specifically for remote sensing applications. The primary goal of this project is to determine, for different forest ecosystem types, the length of time the burn scar will remain visible to mid and long-wave infrared sensors. Since the high-temperature flaming front is in general a transient event, the burn scar may be observable for a significantly longer time than the flaming front. The burn scar usually has a much larger area and higher emissivity than the flaming front, so that significant power may be radiated from the burn scar even though the temperature of the scar is much lower than the flame temperature. It may also be possible to derive the path history of the fire from a remotely-sensed temperature map of the burned-over area, and to make predictions about the future path of the fire.

To perform these measurements we have developed lightweight, portable data recorders (Kremens (2003)) that can simultaneously measure both the kinetic temperature (using thermocouples) and the radiant flux from the forest floor. To measure the radiant flux we use infrared thermopiles (Dexter Research type 2M) with 0.25 - 10 micrometer bandwidth. From the radiant and kinetic temperature histories we can obtain the emissivity as a function of time and the cooling rate of the forest floor. We sample up to 16 separate points during a fire passage which allows for spatial averaging over several scale lengths.

* *Corresponding Author Address:* Robert Kremens, Rochester Inst. Of Technology, 54 Lomb Memorial Dr. Rochester, NY 14623; e-mail; kremens@cis.rit.edu.

2. EXPERIMENTAL METHOD

We have deployed up to 16 thermocouple/radiant flux sensors on prescribed fires in several forest ecosystem types. A data recorder/signal processing unit is buried under 0.1 - 0.2 m of soil. Two - three thermocouple/flux sensor pairs are attached to the logger with fire-resistant wire. The flux sensors are mounted on inexpensive tripods about 2 m above the surface of the forest floor so that the field of view of the flux sensor is centered on the area sensed by the thermocouple. (Figure 1) Data is recorded every 15 seconds before, during, and after passage of the fire. The time constant of the sensors is under 2 seconds. In some cases the flux sensor is destroyed during passage of the fire, but we usually recover the thermocouple (Type K). In cases where the flux sensor is destroyed we use a commercial radiant thermometer - thermocouple to measure the emissivity of the forest floor after fire passage.

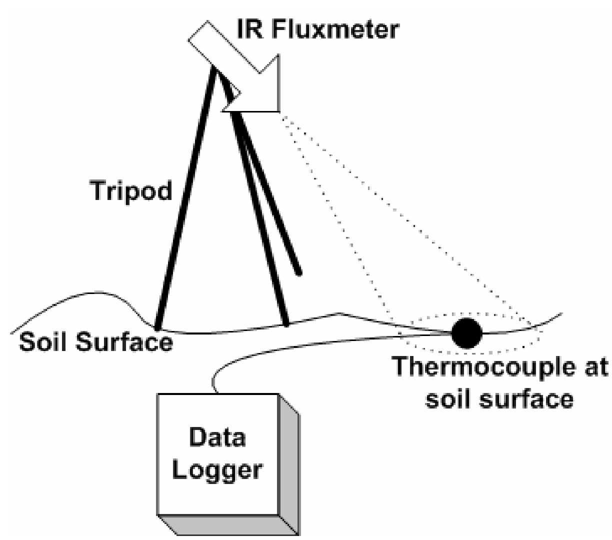

Figure 1: An IR fluxmeter is mounted on a tripod about 2 m above the surface of the soil. The fluxmeter field-of-view is centered on a thermocouple that is in contact with the soil surface. The data from both sensors is logged as a time series by a buried data logger. Up to 3 sensor pairs and two additional thermocouples may be logged by a single logger.

3. PRELIMINARY RESULTS AND DISCUSSION

We present results from a prescribed fire near Albany, NY in a mixed pitch pine/scrub oak ecosystem. The burn unit had been prepared by hydro-cutting the previous spring and the fuel load corresponded to a fire behavior fuel model type 6-7 (Anderson (1982)). The 2950 acre area is managed by the Albany Pine Bush Preserve and the Nature Conservancy. Fire is used as a management tool to exclude invasive species, maintain the historical openness and reduce fuel loading. The Preserve is in a highly populated area just west of the New York State capital of Albany.

The soil at the Pine Bush Preserve is very sandy, well drained and of low to moderate moisture levels. We conducted measurements of surface cooling rates and measured emissivity at two sites. One site was on the north slope and one was on the south slope of a gentle hill, about 100 m apart. We also measured the emissivity before and after the fire for several selected 0.1 m diameter patches near the measurement sites using a commercial IR thermometer (Omega Engineering Model OS534DL).

The fire was conducted on a warm (32C^o) day with relatively low humidity (~40% RH). Wind was light but variable at ~ 10 - 15 mph during the fire. Flame heights of 2 - 5 meters and torching of several large (40 cm DBH) pitch pines was observed.

Time-temperature profiles from the two sites are shown in Figure 2. Peak temperature at the two sites was around 800 C^o. Figure 3 shows the results of a decay time curve fit for the north-facing slope test site using a single time constant exponential decay. A good fit was obtained for all of the thermocouples (6) using a single time constant of about 100 seconds (1/e time). Ground temperatures during a bright sunny day can reach 40 - 50 C^o at this site. Ground temperatures remain above 100 C^o (which should be easily detectable using a long wave infrared aerial camera) for about 270 seconds after passage of the flaming front.

Infrared emissivity of the burned over area generally increased, which further enhances IR observability. Area-averaged emissivity readings (3.5 X 10^{-3} m^2 averaging area) for pre and post burn for the two sites are shown in Table 1.

4. CONCLUSION

We have obtained surface temperature and emissivity measurements for several forest ecosystems during fire events. These measurements allow accurate prediction of detectability of fires and monitoring of the progression of wildfires using remote sensing platforms. We are continuing this work for other forest ecosystems for both wild and prescribed fires.

This work was supported by the National Aeronautics and Space Administration under Grant NAG5-10051 and by the USDA Forest Service under Joint Venture Agreement 03-JV-1222048-049 with the Rocky Mountain Research Station. This financial support has been greatly appreciated.

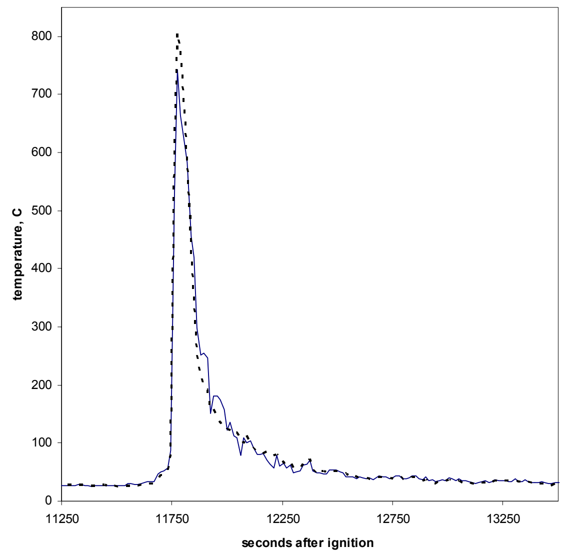

Figure 2: Time-temperature profiles as measured by fine gauge (24 AWG) Type K thermocouples in contact with the soil surface. Dotted and solid curves are from two thermocouples 1 m apart. Data from 6 other thermocouples at this site were very similar with regard to both peak soil temperature and decay characteristics.

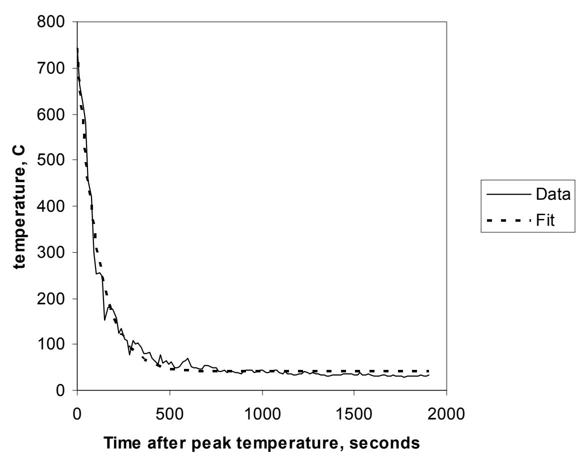

Figure 3: Decay time calculations. The 1/e decay time constant is 110 seconds. The surface temperature remains above 100C^o for almost 5 minutes, at which point the flaming front for this fire had advanced almost 50 m.

Target Description	IR (8-14mm) Emissivity Pre-fire	IR (8-14mm) Emissivity Post-fire
Grass/soil	0.75	0.9
Slash/shrub	0.65	0.85
Bare soil	0.45	0.45

Table 1: Before- and after-fire emissivity averaged over the 8 - 14 μm wavelength region. The emissivity measured is for a spatially averaged 0.07 m diameter area. Some soil was visible through the grass/soil and slash/scrub areas which probably accounts from the deviation of these values from the generally accepted IR emissivity (~0.9) of plant materials.

5. REFERENCES

Anderson, H. E., 1982: Aids to determining fuel models for estimating fire behavior. USDA FS Gen Tech. Report INT-122

Beadle, N.C.W., 1940: Soil temperatures during forest fires and their effect on the survival of vegetation. J. Ecology, **28**, 180-192.

Daubenmire, R. 1968: Ecology of fire in grasslands. Adv. Ecol. Res., **5**, 209-266.

Kremens, R., Faulring, J., Gallagher, A., Seema, A., Vodacek, A., 2003: Intl. J. of Wildfire, **12**, 237-244.

Molina, M.J., Llinares, J.V., 2001: Temperature-time curves at soil surface in maquis summer fires. Intl. J. of Wildfire, **10**, 45-52.