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Performance of high temperature heat flux plates and soil moisture probes during controlled surface fires

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1 Introduction

Natural and prescribed fires play an important role in managing and maintaining most ecosystems in the western United States. The high soil temperatures associated with fire influence forests and their ability to regenerate after a fire by altering soil properties and soil chemistry and by killing microbes, plant roots, and seeds. Because prescribed fire is frequently used to reduce surface fuels, it is important to know how fuel conditions, soil moisture, and soil properties interact to determine the soil temperatures, the depth of the soil thermal pulse, and the response of the soil biota to soil heating. This report presents the results of experimental tests of a high temperature soil heat flux plate and a high temperature soil moisture probe. These sensors are intended to provide data before, during, and after a prescribed burn in support of long term studies of soil microbial response to fires.

2 High Temperature Soil Heat Flux Plates

More details concerning the controlled burn experiments and the soil heat flux and concurrent soil temperature measurements can be found in Massman *et al.* (2003). This section summarizes some of their results and report on the post-fire calibration of the high temperature heat flux sensors.

The high temperature heat flux probes tested in this experiment are available from Thermonetics Corporation (La Jolla, CA). They were installed, along with thermocouples (Figure 1), at a slash pile burn site within Manitou Experimental Forest (southern Colorado) on October 12, 2001 at 0.05, 0.10, and 0.30 m depths (Figure 2). The slash pile was then constructed by hand above the sensors on October 18, 2001. It was approximately conical in shape, 6 m high, and 9 m in diameter at the base. The slash pile was burned on January 11, 2002. The total loading was about 560 tonsM hectare^{-1}.

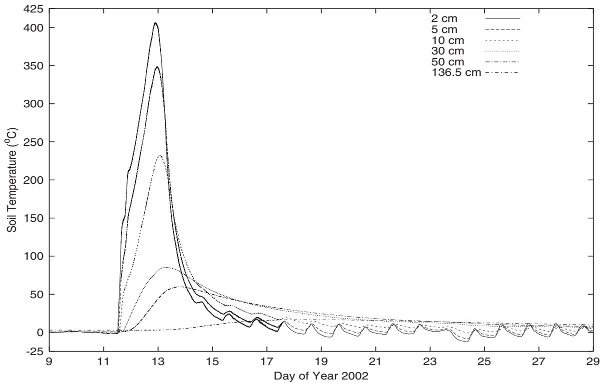

Figure 1: Twenty days of soil temperatures at the slash pile burn site. Time series begin two days before the fire. The fire was initiated about 12:20 PM MST on day 11 of 2002 and burned for several hours.

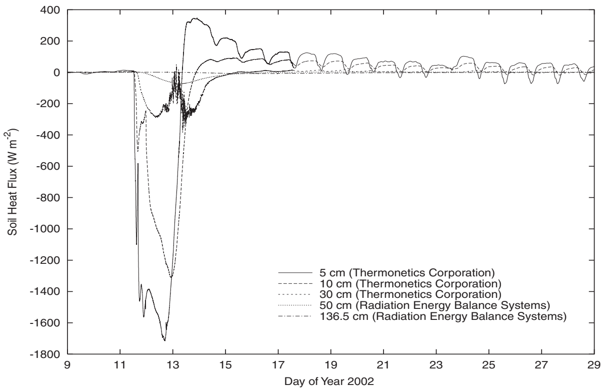

Figure 2: Twenty days of soil heat fluxes at the slash pile burn site. Time series begin two days before the fire. The fire was initiated about 12:20 PM MST on day 11 of 2002 and burned for several hours. The manufacturers of the soil heat flux plates used during this experiment are given in the figure legend.

Two different methods were used to evaluate sensor performance. The first involved comparing the observed soil heat flux data to similar data from the only other comparable experiment we are aware of (Tunstall *et al.* 1973). The comparisons were favorable and the results of both experiments agreed. Tunstall *et al.* (1973) observed a maximum surface heat flux of about 2000 W m^{-2} and the present study suggested that the maximum surface heat flux was about 2350 W

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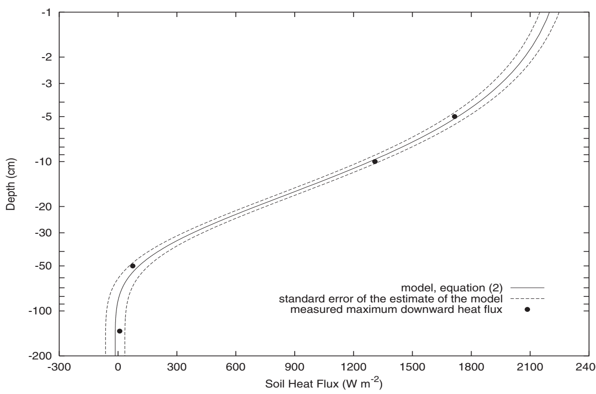

Figure 3: Vertical profile of maximum measured soil heat fluxes (●) and the corresponding curve fit with an exponential decay function at the slash pile burn site. By extrapolation the maximum surface heat flux was about 2350 W m^{-2}.

m^{-2} (Figure 3). The second validation test involved retrieving the heat flux plates and checking their calibration against their original calibration factors. All post-fire calibrations were within ± 10% of their original values.

3 High Temperature Soil Moisture Probe

The test of the high temperature soil moisture probe was performed May of 2003 at a campfire site near the headquarters of the Manitou Experimental Forest. The sensor was a prototype TDR designed and fabricated by Zostrich Geotechnical (Ellensburg, WA). The campfire site was excavated and the stainless steel needles of the sensor were installed at a nominal depth of 5 cm. Simultaneous soil and probe body temperature measurements were made with thermocouples. The hole was backfilled and a cup or so of water was added to the soil. The fire was initiated about 1 pm (MDT) on May 8. Fuel was added to the fire at irregular intervals until about 4 pm (MDT) May 9. The sensor and thermocouples were retrieved on May 14.

Figure 4 shows the soil moisture data obtained during the week of May 8 - 14, 2003 and Figure 5 shows the concurrent temperatures. The sensor performed well during the drying portion of the experiment (days 128-130). The early increase in measured soil moisture is attributed to the downward movement of the water that had been added to the soil surface just prior to the construction and initiation of the fire. However, after day 130 the sensor began to fail and performed intermittently after that. Subsequent lab examinations suggested that the Teflon coated coaxial cable had melted in places and had exposed the cable wires to the soil (and any remaining soil moisture). Nevertheless, and remarkably, after taping the coaxial cables with electrical insulating tape the sensor performed in the lab as expected and it was impossible to cause it to fail again. According to the temperature data (Figure 5) the sensor began to fail when the top of the coaxial cable reached about 240 C, which is near (but a bit below) the 260 C melting point temperature of Teflon.

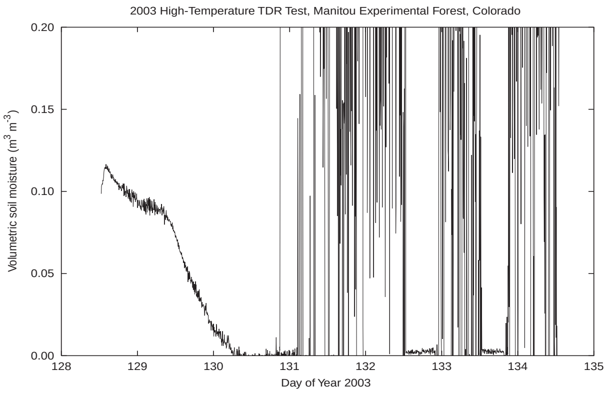

Figure 4: Seven days of soil moisture probe data at the campfire site. The fire was initiated about 1 pm (MDT) May 8 (day 128), 2003. The probe began to fail about day 131, but preformed intermittently on days 132 and 133. The probe was retrieved on day 134.

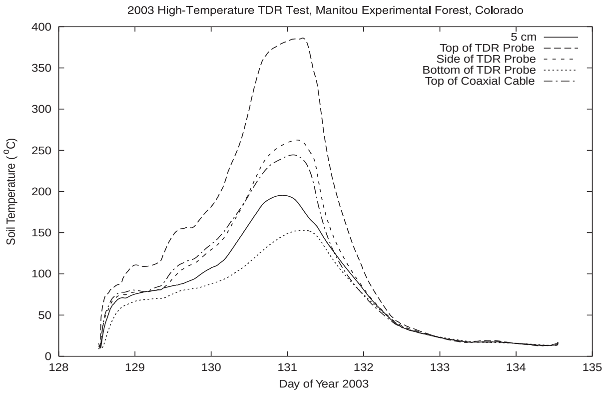

Figure 5: Seven days of soil moisture probe and soil temperature data. The experiment began midway through day 128 and ended mid way through day 134.

Figure 6 shows the pre- and post-fire TDR calibration data performed using soils characteristic of the site. The post-fire calibration data were within ± 0.02 (absolute units of θ_v) of the original calibration.

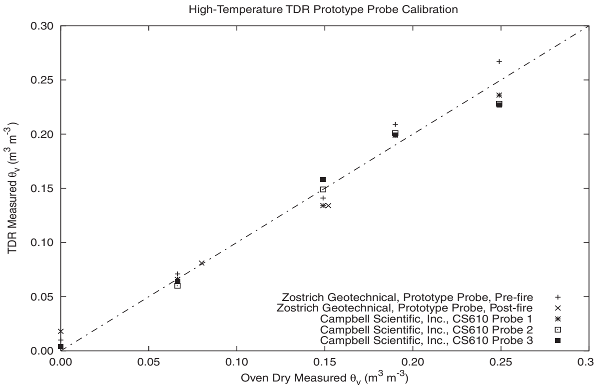

Figure 6: Pre- and post-fire calibration of the high temperature TDR soil moisture probe. The calibration used soils native to the site and the physically based model of Topp *et al.* (1980) with empirically determined coefficients.

4 Conclusions

All results to date suggest that the high temperature heat flux plates performed reliably.

Present results suggest that the high temperature soil moisture probe performed very well and possibly better than expected. Post-fire examinations have suggested a few simple design changes in the probe and further tests are planned.

References

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