Simulating Ground Thermal Anomaly under Conditions of Dense Vegetation Based On Lab and Field Measurements to Support Thermal Infrared Remote Sensing Techniques

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ABSTRACT

The ground temperature and emissivity anomalies could be used as an indicator for the existence of geothermal surface manifestations such as hot springs, fumaroles, or altered surfaces with remaining thermal at a crater rim. The ground temperature could be measured directly at the field using ground thermometer. However, field measurements are inefficient for large investigated areas and extracting Land Surface Temperature (LST) based on satellite thermal infrared sensor is also complicated due to several unknown parameters such as noise from the environment and object emissivity. Moreover, field studies under the conditions of dense vegetation makes the problem worse due to the shallower layer penetration of the response at wavelengths of thermal infrared compared to microwave energies. Overcoming the problem, we tried to estimate the kinetic temperature from the simulated steam spot using thermal infrared camera FLIR C2 with an accuracy of 2°C. The lab simulations were performed proportionally to ground variables such as the vegetation cover, height of the sensor, and diurnal effects. According to the simulations, the steam spot from boiling water 98°C recorded by the sensor at heights more than 1.2 m equivalent to spatial resolution 0.2 cm is constant about 37.2°C. We also observed that the vegetation cover reduced the measured temperature with thermal efficiency 33%. For diurnal effect, the detected temperature is constant regardless time observations. The background temperature influenced the vegetation covering steam spot with efficiencies 30% and 50% for day and night observations, respectively. These simulation results were used for further study into thermal infrared remote sensing techniques for thermal features identification. Field investigations were also performed to clarify the applicability of the thermal infrared camera to the measured ground temperature.

1. Introduction

The temperature and emissivity anomalies extracted from thermal infrared (TIR) remote sensing could be used as an indicator for the existence of geothermal surface manifestations such as hot springs, fumaroles, mud pools, and steaming ground (Hodder, 1970). The ground temperature could be measured directly at the field using contact system such as ground thermometer. However, field measurements are inefficient for large investigated areas (Saepuloh et al., 2013). The laboratory and field experiments presented in this paper are aimed to support thermal infrared remote sensing for geothermal features detection (Kuenzer and Dech, 2013).

Extracting kinetic temperature of ground target based on satellite thermal infrared is complicated due to several unknown parameters such as emissivity and noise from environment (Kahle and Alley, 1992). Therefore, brightness temperature is the most optimal applicable parameter to assess the ground thermal anomaly in assumption that the atmospheric effect is not significant (Jiménez-Muñoz and Sobrino, 2003). Moreover, investigated field study under conditions of dense vegetation makes the problem worse due to the shallower layer penetration of the response at wavelengths of thermal infrared compared to microwave energies (Saepuloh et al., 2012).

In this study we simulated the “steam spots” as detected by the thermal infrared camera using a boiling water to obtain the effect of sensor height and variation of vegetation cover as well as diurnal temperature to the measured steam spot. We also calculated the effect of resolution to the measured temperature and efficiency of vegetation covers reducing temperature of targets. In addition to the lab measurement, we also measured ground temperature at mud pool, steaming ground (altered surface), and hot spring using the same thermal infrared camera.

2. Equipment and method

Detecting kinetic temperature of the objects at ground surface level is the aim of the thermal infrared remote sensing. Straight forward to the problem, we applied a simulation to estimate the kinetic temperature from a steam spot using thermal infrared camera FLIR C2. The FLIR C2 is a pocket-sized thermal camera and designed for a wide range of applications to find heat patterns that point out hotspots. The camera was utilized by visible (VIS) and infrared (IR) sensors with spectral range 7.5 - 14 µm and resolution 640×480 pixels for VIS and 80×60 pixels for IR sensor (FLIR, 2014). The object temperature range -10°C to 150°C with accuracy ±2°C makes this camera is plausible for measurement at geothermal field.

Measuring the target temperature, a static 200 cm vertical road was used as center of the height adjustable camera positions. Then, the steam spot was simulated using boiling water which is maintained temperature at 98°C by a heater pot and located at the bottom part of the vertical road (Figure 1). The lab simulations were performed proportional to ground variables including height of the sensor, vegetation cover, and diurnal effect. To obtain the elevation and the resolution impact to the measured temperature, the steam spot was measured every 5 cm height. The minimum and maximum heights are located at the pot cover (=0 cm) and top of the road (=200 cm), respectively. According to this method, the camera produced 40 measurements from different height. For analyzing vegetation cover to the measured temperature, we used leaves cover 0, 25, 50, 75, and 100% of total upper pot surface area. Cover 0 and 100% mean that the upper pot are opened and closed totally by vegetation, respectively. This experiment will support the evidence of temperature relationship for partial canopy cover conditions (Kustas and Anderson, 2009). To obtain the air temperature variation over time to the measured temperature, we measured the steam spot every hour in open area for 24 hours. The measurements were performed using fixed height 200 cm and vegetation cover 0 and 25%.