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Infrared and hyperspectral remote sensing of Earth degassing

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Abstract. Geodynamical processes often cause degassing at the Earth surface via mineral springs, water mofettes, or dry mofettes. It is assumed that the emerging gas influences the temperature of the soil at and around the dry gas vents. This causes a thermal anomaly in comparison to the close vicinity. Investigations have commenced to determine whether the effect can be utilised to detect gas emanations through airborne infrared imaging measurements. As a first approach, compressed air was lead into the ground and released in some depth. The thermal effect at the surface was observed by a thermovision camera. Furthermore field measurements have been conducted in the Western Bohemia (Czech Republic) earthquake swarm region where especially CO_2 emanates.

In parallel eco-physiological studies are conducted to determine the influence of the escaping CO_2-gas on the plant communities growing within the varying CO_2 concentrations within the mofette fields (see abstract Pfanz et al.), concentrating on parameters of plant physiology and the plant spectral signature. Especially the chlorophyll content can expose anomalies which again might be detectable using hyperspectral remote sensing instrumentation.

1 Introduction

From the geo-scientific point of view the Earth crust and upper mantle below West Bohemia and the Vogtland are unique due to periodically recurring swarm earthquakes and to the proven combination of seismic activity and high flux gas emanation in extended areas (Weinlich et al., 1999). To date the cause of the crust behaviour "swarm earthquake" is not well understood. A scientific solution requires, among other, a survey and mapping of the majority of gas rich springs as well as water and dry gas vents to establish a solid basis for further investigations like the local interrelation of geological faults and gas vents, the total gas flux rate and its variability, the interrelation of seismic activity and gas flux rate, etc. As a first step a method is being established to allow for the detection of gas emitting vents in a wide area within a short time. The approach proposed and described here aims at the application of airborne infrared imaging instrumentation to detect soil surface thermal anomalies which are caused by emanating gas. In preparation of systematic investigations in West Bohemia a simple experiment has been performed to achieve first qualitative understanding of the thermal effect of gas emanating the earth surface. Field measurement in West Bohemia have been conducted subsequently.

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2 Thermal behaviour of dry mofettes

Regarding dry mofettes it can be stated that the surface temperature of bare or vegetation-covered soil surfaces is primarily determined by the soil properties (thermal conductivity and capacity, moisture, radiative absorbance, etc.), the impinging radiation (sun), and the weather (air temperature, wind, clouds, rain etc.). Areas of soil which can be considered as homogenous with respect to the parameters of influence will therefore adopt a fairly uniform surface temperature. Any disturbance of the homogeneity will cause thermal anomalies of the soil surface. These can be detected if they are local with respect to the otherwise homogeneous area. This is the case with many of the dry mofettes. The mofette gas thermal forcing is superimposed to all other thermal effects and restricted to the close vicinity of the gas outlet.

3 Experimental set-up

Emerging gas was simulated by releasing compressed air in about 20 cm depth in the ground of a mowed meadow. Thermocouple sensors were used to determine the soil temperatures at the gas outlet and at an offside location for comparison. Soil surface temperature distribution was observed by an infrared camera AGEMA 570 at a distance of approximately 4 m from the lance. Its spectral range is $7.5 - 13\,\mu$m wavelength. The field of view FOV $= 24° \times 18°$, the spatial

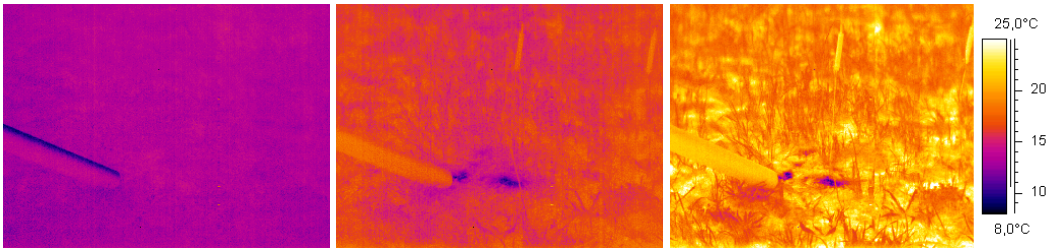

Fig. 1. Temperature distribution at gas release area. The lance appears in the lower left side of the images, the gas emanations above its buried tip. Left, 09:00 LT, shadow, gas flow just turned on. Middle: 11:30 LT, shadow, thermal effect of emanating gas obvious. Right: 12:05 LT, sunshine, gas thermal effect maintained.

resolution is 1.3 mrad, the temperature resolution NEΔT = 0.15 K @ 300 K.

4 Experiments and results

Experiments were performed on 13 August 2002 beginning at 09:00 LT Local Time when the gas flow was turned on. During several hours the ground surface temperature was periodically monitored with the infrared camera. Three of the recorded images are shown in Fig. 1. At 09:00 LT, when the experiment area was fully shaded, the temperature of the whole scene is fairly homogeneous and around 13°C to 14°C (left image of the figure). At 11:30 LT the soil surface temperature above the lance's gas outlet is 11°C and 12°C and differs significantly from the surrounding of about 17°C. Hence the emanating gas cools the surface. At 12:05 LT, after having been exposed to direct sunshine for about 30 min, the area is now thermally inhomogeneous: spots on the soil have taken a temperature up to 24°C to 25°C, whereas the grass temperature is as low as about 16°C, the mean is 18.2°C. The surface temperature at the two gas outlets is 14°C and 15.4°C.

5 Conclusions

Whereas the temperature distribution of the ground surface is strongly influenced by intermitting sunny and shady periods the thermal imprint of the emerging gas remained clearly superimposed, i.e. a difference between both temperatures sustained, though not constant. The process is dynamical and obviously strongly depending on the gas flux. Temperature differences as high as 5°C were observed. The results encourage to continue the investigations. Determination of most favourable conditions with respect to season, time and weather should pave the way for airborne monitoring of dry mofettes.

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