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Detection of cave entrances with airborne thermal imaging

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The knowledge about the occurrence, size and enlargement of caverns in Karst areas is a prerequisite for the protection of potable water and for tunnel engineering purposes. A common approach for speleologist is the detection of the entrances of a cave on foot in the field and mapping its spatial dimension, based on parameters measured on site. Imaging sensors, sensitive to airflow temperature differences, may support the cave entrance detection. In this study the requirements and limitations to detect cave entrances by using an airborne thermal imaging sensor, flown on a helicopter platform, are evaluated.

The air temperature of the off-cave atmosphere vary in order of some tens of degrees centigrade with the season, whereas the intra-cave air vary only in order of some few degrees. This thermal disequilibrium is often responsible for a characteristic convective air circulation (cave wind) in lager cave systems with multiple entrances. During summer season, when the cave air temperature is lower than the temperature of the external atmosphere, the relatively dense cave air exhausts by the lower entrances of a system. In winter we have the inverse situation and the cave air soars to the upper entrances. The aim of the presented approach is to map cave entrances by detecting the temperature differences of air outflows to the surrounding background, using thermal imaging. In this study a Super Puma helicopter equipped with a Forward Looking Infra Red (FLIR) camera was used.

The study area is a karst terrain in the region of Melchsee-Frutt, canton of Obwalden, Switzerland. The study area includes three well known cave systems with lengths

between 5 and 20 km at an altitude of 1700 to 2500 m a.s.l. The entrances are located at different altitudes within a vegetation varying from forest (lower area) and bush coverage (middle area) to grass and bare karst (upper area).

A first challenge was to investigate the ideal flight conditions with focus on an optimized contrast of temperature between surface background and outflowing cave air masses. Theoretical models as well as elaborate field observations and measurements from known cave systems in the study area helped to determine the required temperature difference between cave and off-cave air which results in a convective air circulation. It was shown, that in the study area a temperature difference between the cave air and the external atmosphere of about 6 ˚C is required to cause an air circulation.

A thermal imaging campaign in winter 2005 resulted in determining 12 potential objects and a following campaign in summer 2005 allowed for detection of three new caves. No further cave entrances were detected by orthorectified images of a third campaign (winter 2006) due to either snow cover and illumination conditions or missing cave air circulation. However our research demonstrates that thermal imagery is basically an option to detect cave entrances.

Determining factors for a successful thermal airborne imaging campaign were enabled. Direct illumination conditions should be avoided. Cloudy weather or night flight campaigns are suggested. Low windspeed within the surface atmospheric layer and specially a thermal disequilibrium on off- and intra- cave atmosphere are precedent to be effective .

In many case flight conditions, fundings and technical availabilities are limited. Ground based thermal imaging sensors could be another, more efficient, alternative. However there is still a lot of research needed in order to reach an automatic identification and mapping procedure for cave entrances and an applied suitable workflow.