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Thermal Imaging of Subsurface Coal Fires by means of an Unmanned Aerial Vehicle (UAV) in the Autonomous Province Xinjiang, PRC

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Spontaneous combustion of coal and resulting coal fires lead to very high temperatures in the subsurface. To a large amount the heat is transferred to the surface by convective and conductive transport inducing a more or less pronounced thermal anomaly. During the past decade satellite-based infrared-imaging (ASTER, MODIS) was the method of choice for coal fire detection on a local and regional scale. However, the resolution is by far too low for a detailed analysis of single coal fires which is essential prerequisite for corrective measures (i.e. fire fighting) and calculation of carbon dioxide emission based on a complex correlation between energy release and CO2 generation.

Consequently, within the framework of the Sino-German research project „Innovative Technologies for Exploration, Extinction and Monitoring of Coal Fires in Northern China", a new concept was developed and successfully tested. An unmanned aerial vehicle (UAV) was equipped with a lightweight camera for thermografic (resolution 160 by 120 pixel, dynamic range -20 to 250°C) and for visual imaging. The UAV designed as an octocopter is able to hover at GPS controlled waypoints during predefined flight missions.
The application of a UAV has several advantages. Compared to point measurements on the ground the thermal imagery quickly provides the spatial distribution of the temperature anomaly with a much better resolution. Areas otherwise not accessible (due to topography, fire induced cracks, etc.) can easily be investigated.
The results of areal surveys on two coal fires in Xinjiang are presented. Georeferenced thermal and visual images were mosaicked together and analyzed. UAV-born data do well compared to temperatures measured directly on the ground and cover large areas in detail.

However, measuring surface temperature alone is not sufficient. Simultaneous measurements made at the surface and in roughly 15cm depth proved substantial temperature gradients in the upper soil. Thus the temperature measured at the surface underestimates the energy emitted by the subsurface coal fire. In addition, surface temperature is strongly influenced by solar radiation and the prevailing ambient conditions (wind, temperature, humidity). As a consequence there is no simple correlation between surface and subsurface soil temperature.
Efforts have been made to set up a coupled energy transport and energy balance model for the near surface considering thermal conduction, solar irradiation, thermal radiative energy and ambient temperature so far. The model can help to validate space-born and UAV-born thermal imagery and link surface to subsurface temperature but depends on in-situ measurements for input parameter determination and calibration.

Results obtained so far strongly necessitate the integration of different data sources (in-situ / remote; point / area; local / medium scale) to obtain a reliable energy release estimation which is then used for coal fire characterization.