Detection, Analysis and Risk Assessment of Coal Fires in northern China

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Uncontrolled combustion of coal is a serious problem on a global scale. This phenomenon can be found on every continent. In many regions of the world, coal seams crop out at the earth's surface and thus get in contact with oxygen. Since coal can easily be oxidized and often has a prominent "self-heating" capacity, many coal types have a tendency to combust spontaneously once sufficient oxygen is available for the process and natural cooling is prevented. The rapid expansion of uncontrolled small-scale coal mining activities in remote areas during the last 30-40 years and the increasing amount of not adequate closed down and now abandoned coal mine sites are supposed to have led to an increase of human-induced coal fires.

China is the biggest producer of coal in the world and mines about 2.4 billion tons of raw coal per year. Approximately 70 % of Chinas energy consumption is covered by coal. Especially the arid and semi-arid belt in North China stretching from Xinjiang in the west to the Pacific Coast in the east is affected by numerous, probably thousands of coal fires of various dimensions. This fire belt extends over a huge area of 5000 km east-west and 750 km north-south. Beyond the horrendous economic losses resulting from uncontrolled combustion of high quality coal deposits, another problem is the environmental impact that results from coal fires, e.g. devastated landscape, soil loss and large amount of toxic greenhouse gas emissions such as CH4, CO, and CO2 are emitted from the fires polluting the atmosphere.

Being aware of the scientific as well as technological deficits that are evident with regard to today's knowledge about preconditions, processes, geometry, and dynamics of coal fires, the project focused on generating a better scientific understanding for detection and quantification of coal fires. Comprehensive risk assessment studies are based on the combination of image derived land-use and land-cover in combination with geological background and mining related information to synthesize parameters that can be used to delineate regions, which are highly prone to coal fire occurrences. To improve transferability of the approach developed so far, selected regions have been investigated in more detail, trying to take the inherent uncertainty of the different data sets into account. Besides image derived information on land-cover and land-use classes, remote sensing in the thermal infrared part of the electromagnetic spectrum significantly contributes to the detection and monitoring of coal fires in those affected areas. An adequate parameter for coal seam fire characterization is the coal fire related energy release (CFRE). Investigations have been focused on adequate image pre-processing routines, empirical solutions estimating the long-term background temperatures on non-vegetated soils and rocks and on model developments describing the surface energy balance. These aspects aim in a better estimation of surface heating caused by solar radiation, which is an important prerequisite to validate image derived CFRE information. Thus, environmental impact and risk assessment of fire sites, both at a local and regional scale, integrated into Geographic Information Systems and combined with other data relevant to environmental concerns, are invaluable for advanced modeling approaches to quantify coal fire emissions.

International research cooperation has been focused on detection and quantification of coal fires as well as the development of verifiable and reliable methods for greenhouse gas emission modeling. This includes support for integrating coal fire extinguishing activities in national and international CO2-trading schemes. Although important developments have been made, open issues remain in the domain of securing extinguished coal seams or those seams prone to coal fires in long-term perspective. In order to improve coal fire-fighting approaches, taking time and costs into account, monitoring, observation and securing techniques need to be developed, tested, and implemented. Thus, coalfield fires need to be not only inventoried at regional scales through rapid and cost effective methods, but also assessed and monitored and secured at in-situ scale, wherever appropriate. This leads to major research and technological development objectives: Easy-to-use, routine remote and in-situ monitoring techniques, based on airborne and space borne imagery, geophysics and thermal infrared spectrometry, to be applied in an integrated long-term monitoring framework.

中国北方煤田火灾的探测，分析与风险评估

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不受控制的煤田火灾是一个全球范围的严重的问题。在很多地区,由于开采等原因，煤层暴露在空气中,从而接触氧气。由于煤炭可以很容易被氧化　并迅速升温,许多类型的燃煤一旦接触到足够的氧气会发生自燃。　偏远地区在过去的40年里,快速扩张并不受控制的小规模煤炭开采活动迅速增加，以及废弃煤矿的增加，都导致了人为原因诱发的煤田火灾的增加　中国是世界最大的产煤国，年产约约24亿吨原煤。中国的　能源消费大约70%是靠煤炭。中国北方从新疆西部到　东太平洋沿岸的干旱和半干旱带受到众多的煤田火灾威胁，这一火带扩展在　东西5000公里和南北750公里的巨大范围内。除了造成可怕的经济损失外,还带来了严重的环境问题，例如　对景观的破坏、土壤流失和大量的温室气体排放（如甲烷,CO和CO2）和空气污染。

考虑到对煤田火灾发展过程、动力学特点等认识不足，　项目研究集中在对煤田火灾更好的科学理解和探测。基于图像提取的土地利用和土地覆盖，　结合地质背景和采矿相关信息的综合参数,进行了全面的风险评估，可用来确定易发生煤田火灾区域。　对选定的区域进行了更加仔细的研究，试图把内在的不确定性考虑进去以改进使用的方法。　除了基于图像提取的土地利用和土地覆盖信息外,热红外遥感数据也被使用于监视的受煤田火灾影响的地区，　被用于一个表征煤火相关能量释放(CFRE)的参数。发展合适的图像处理方法以支持无植被覆盖的土壤和岩石长期背景温度的估算　描述表面能量平衡模型的发展。这些研究的目标是对太阳　辐射对地表加热的更准确的估计,这是从影像中估算CFRE时必须要有的一个重要参数。无论是在局部还是区域范围内,将环境影响和风险　评估结果与其他与环境有关的数据集成到地理信息系统中,对于发展模型以量化煤火排放都是很有价值的。

国际合作研究集中在检测和定量分析煤田火灾以及发展可验证　和可靠的温室气体排放模型,以支持煤炭灭火活动国际碳交易方案。为了提高煤灭火　效率,并将时间和成本考虑在内,监测和观察技术需要进一步开发,测试,以及　实现。因此,需要进一步发展将易于使用的常规的远程和现场监测技术、基于卫星和航空遥感的方法、地球物理学和　热红外光谱法应用于一体的综合性长期监测系统。