Extinguishing the Fire – Saving the Environment with Satellites?

Field Work

Coal fires are known from many coal fields world-wide. China, India, USA, Australia, Indonesia and South Africa are the main countries affected by coal fires.

Normally, the mine workers and the people living in the surrounding areas are adversely affected by large amounts of aerosols and toxic gases but also greenhouse-relevant gasses are being released in large quantities and affect the global environment. Additional severe hazards include land-subsidence, contamination of drinking water and damage of flora and fauna around the fires.

Protecting the economically valuable coal as energy supply without jeopardizing the environment is of great relevance on national and international level in particular in view of the never ending discussions about the increase/decrease of the number of atomic power plants and the most recent oil spill in the Gulf of Mexico.

Field work coal fire research 2002

The uncontrolled combustion of coal discharges big amounts of toxic gases like carbon monoxide or sulphur oxides and nitrogen oxide as well as climate active greenhouse gases like carbon dioxide and methane which contribute to the heating of the atmosphere and to the global warming.

China's coal fires consume an **estimated 20 million tons of coal per year** but it is assumed that about ten times more coal is lost and can not be mined anymore in the vicinity of still burning or already extinguished fires. The fires in China emit as much as 60 million tons CO_2 annually **that is approximately 7 % of Germanys total $C0_2$ emission in 2006**.

In addition to the production of toxic gases, changes and destruction of the affected landscape as a result of land-subsidence are particularly relevant for urban regions. Therefore coal fires are a global issue and subject of international scientific cooperation.

The map shows main coal fire regions of the world.

World Map

China is the largest coal-producer and coal-consumer in the world. However a huge amount of coal resources get lost by uncontrolled coal fires. These fires occur within a region that stretches over 5000 km east-west and 750 km north-south in the northern part of China. Before attempting to extinguish a near-surface coal seam fire, its location and underground extent must be determined as precisely as possible. Besides studying the geographic, geologic and infrastructural context, information can be gained from direct measurements. These include temperature measurements of the land surface, in fissures and boreholes as well as gas measurements to characterize the fire ventilation system (amount and velocity) and the gas composition, so that the combustion reactions can be described. Finally geophysical measurements on the ground and from airplanes and helicopters to establish the extent of conductivity or other underground parameters and remote sensing from aircraft and satellites are of importance.

World Map of coal fires (Copyright DLR 2002)

High resolution optical mapping, thermal imaging and hyperspectral data play a role. Underground coal fires of several hundred to over a thousand degrees Celsius may raise the surface temperature by only a few degrees. This order of magnitude is similar to the temperature difference between the sunlit and shadowed slopes of a slag heap or sand dune. Infrared detecting equipment is able to track the fire's location as the fire heats the ground on all sides of it. However, remote sensing techniques are unable to distinguish individual fires burning near one another and often lead to undercounting of actual fires. It is also difficult to distinguish coal seam fires from forest fires.

The **Sino-German Coal Fire Research Initiative** (http://www.coalfire.caf.dlr.de) was started in 2003 with Phase-A activities studying geometry and dynamics of coal fires as well as self ignition and spontaneous combustion, followed by a Phase-B projected to be completed in

2010. In order to facilitate the international knowledge exchange between researches the coalfire research platform (http://www.coalfire.org) was established.

The **Cologne (Germany) based HarbourDom GmbH** (http://harbourdom.de) is actively supporting Sino German project sponsored by the German Federal Ministry of Education and Research (BMBF) by having appointed Prof. Dr. Horst Rueter (rueter@HarbourDom.de) as responsible as Senior Scientific Advisor for the Coal Fire Research project.

The **German Aerospace Center (DLR)** with its German Remote Sensing Data Center (DFD) at Oberpfaffenhofen, participates with a group of Remote Sensing (RS) specialists (Dipl.-Geoinf. Christoph Ehrler et al.) led by Dr. Christian Fischer (http://www.dlr.de).

SpaceOps News (SoN) had the opportunity for an e-mail interview with the Scientific Advisor of the Coal Fire Research project Horst Rueter and Christoph Ehrler.

SoN: **DLR participated from the very beginning in the Coal Fire Research project in 2003 for detecting and measuring the extent and progression of coal fires in the Inner-Mongolia Autonomous Region, P.R. China, by taking advantage of remote sensing satellites. Which type of satellites provided the most useful information?**

The project focuses on coal seam fires which are a subsurface phenomenon. The fire can not be seen directly but it causes a temperature anomaly at the topographic surface. This anomaly is dependent on the depth and extent of the coal fire but is also strongly influenced by the overlaying strata, vegetation and the climate. In contrast to vegetation fires the temperature anomaly of a subsurface coal fire is weak and thus hard to distinguish from the background. To maximize the contrast we used night-time imagery of satellites that record the emitted thermal infrared radiation. Research showed that imagery of the German Bi-Spectral Infra-Red Detection (BIRD) experimental small satellite mission and of the U.S.-Japanese Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) were the most suitable satellites.

SoN: Were images of other non-European satellites accessed and processed as well?

In addition to aforementioned ASTER and BIRD we examined Landsat Enhanced Thematic Mapper (ETM+) and the China-Brazil Earth Resources Satellite (CBERS). ETM+ suffered a scan mirror failure in 2003 rendering its data not usable for coal fire applications. CBERS data is hard to analyze due to a lack of accessible information about the sensor characteristics, however this is currently under investigation. As for the future, we plan to test the capabilities of BIRD's successor TET (Technologieerprobungsträger), which is currently under construction at the DLR.

SoN: Was the satellite coverage and quality of the data sufficient for reaching the Phase-B goals?

Due to the low amount of energy transported by thermal infrared radiation the pixel size of the imagery is generally coarse. For ASTER it is 60 m, for BIRD it is 370 m. Of course a better resolution is desired but this would lower the revisit frequency making coal fire monitoring more difficult.

SoN: Was it necessary to develop specific interpretation and analysis S/W?

Most methods for fire detection and quantification were developed for vegetation fires with flaming combustion in the typical temperature range of 800 K to 1500 K. Instead smoldering coal fires leave a surface temperature anomaly of 300 K to 600 K. Hence it was necessary to develop specialized detection and quantification algorithms that can cope with the low contrast and high temporal variability between fire and background temperature. The coarse pixel resolution made it necessary to use sub-pixel approaches that can separate the mixed signal of a pixel into a fraction covered by fire and a fraction covered by background.

SoN: Coal fires seem to be a long-standing problem in the many affected countries. What significant break-through could be contributed by using remote sensing techniques?

Localisation and temperature messurements are essential in the description and characterisation of coal fires and fire zones. Terrestrical measurements are time consuming and so Remote Sensing (RS) can contribute significantly to the 'upscaling' from a single fire or firezone to a continental or even global scale. Estimating the size (heat power) of a fire the energy release is the critical parameter to be measured. The radiated energy release can be estimated by RS. This results in an underestimation (conservative estimation) as only radiation is taken into account and all other forms of energy release are not seen by satelites. The conservative estimation of energy release is also the main input to baseline estimations used for Cleam Development Mechanism (CDM) based financing of fire fighting processes.

SoN: Since the Coal Fire Research work has high political visibility – do you get a more than usual support from institutional organizations for the Sino German research project and how are the costs shared between the international participants?

The German research project as part of the Sino German Research Initiative is fully financed by the German BMBF. The Chinese activities break up in several smaller projects with different funding as from MOST (Ministry of Scienece and Technology) or Industry groups as Shenhua Mining.
In additon the German Ministry for Economical Cooperation (BMZ) financed a GTZ - (German Society for Technical Cooperation) projekt for technology transfer in this field.

SoN: Are the non-controllable coal fire emissions taken into account for the global emission trade?

There was a Chinese application to establish a methodology as part of the Clean Development Mechanism (CDM) procedures and thus Certified Emission Reduction (CER) trading. The methodology was not accepted in the first round of discussions because not sufficient explanation with regard to *additonality* and *sustainability* could be provided. For the *additionality* it has to be shown for each individual fire that it is man-made. For the *sustainability* it has to be shown that no restart of the fire is possible for eternal times. This could be done 1. by mining the coal or 2. by a state controlled monitoring and reaction measures or a combination of 1 and 2. i.e., monitoring until the coal is mined completely. So far no solution could be found.

SoN: Would you expect a growing international, institutionalized effort on coal fire research and containment after completion of the Sino German Phase-B activities since the invested money seems to have an unusual high, direct benefit for the affected contries and the international community?

The German project will end in August 2010. Currently there is no tangible chance to continue this project. The 2. International Conference with more then 120 participants from over 20 countries and more then 50 scientific contributions this year demonstrated the great international interest in this research topic. It is hoped that somewhere in the world funds will be available for further research. Research can only accompany fire fighting activities and research depends on practical application. China is prepared to spend a lot of money for fire extinction in the next years but a real acceleration of extinguishing most of the thousands of fires will only be possible if finacing from the international finance markets is available as from CER trading.

SoN: Could the know-how gained by the project also be of help in supporting the development of innovative and efficient coal fire extinction methods and could those be relevant for forest fires as well?

Research contributet a lot to the localisation and detailled description of fires which of course forms the basis for extinction lay outs. The entire process was sped up and fires are now extinguished much faster wich avoids months of unnecessary gas emission. Innovative extinction technologies as using salt instead of fresh water could only be researched in principle and not tested in pilot projects because of insufficient funding.

An important connection to forest fires is that forest fires may ignite coal fires and vice versa. So extinction of coal fires is important for forest fire prevention.

SoN: Are there any goals postulated for the current Sino German project to actually reduce CO_2 emissions from coal fires?

As mentioned the project ends in August 2010. No further goals are postulated. However we know that the research results will strongly influenc the inner-Chinese goals for coal fire extinction in the coming years.

SoN: What results could be expected in the most favorable case with respect to coal fire containment and emission reduction in the long-run?

Methods to extinguish coal fires are established. Powerfull fire fighting departments exist in different Chines provinces as in Xingjiang. The Chinese governement etablished a priority list for the extinction works in the coming years. The list is economy driven and a main motivation is saving coal for mining purposes and thus fires close to existing or planned mines are preferred. Additional financing like from CER trading could speed up the process significantly. Even fires far away from any mining could be fighted. Unfortunately new fires will start but with enough funding available there would be realistic hope that the entire situation could be kept on a constant level much below today's situation.

Songhutou
Songhutou area coal fire pollution

Prof. Dr. Rueter, we thank you and your collegue Christoph Ehrler very much for the opportunity to talk to you.
We would like to wish you and your international science collegues good luck for making as much progress as possible in this very decisive field of research even though it looks like that unfortunately the efforts will slow down after termination of the Sino German Project.

Dr. Joachim Kehr Editor SpaceOps News (August 2010)