Environmental Monitoring of Coal Mining Subsidences by Airborne High Resolution Scanner

Christian Fischer[1], Volker Spreckels[2]
[1]Technical University of Clausthal, Institute for Mine Surveys, Erzstr. 18, D-38678 Clausthal-Zellerfeld,
phone ++49 / 2041 161 312
fax ++49 / 2041 161 333
christian.fischer@dg.deutsche-steinkohle.de

[2]University of Hannover, Institute for Photogrammetry and Engineering Surveys, Nienburger Straße 1, D-30167 Hannover,
phone ++49 2041 161 310
fax ++49 / 2041 161 333
volker.spreckels@dg.deutsche-steinkohle.de

ABSTRACT

Due to legal requirements the German hard coal mining company ”Deutsche Steinkohle AG” (DSK) is obliged by assessments on environmental impact to make a prognosis and to forecast influences caused by current excavations. Important data needed are ”Digital Terrain Models” (DTM) which describe the topographic situation, information on biotopes and the actual land-cover. Today these data are generated by methods of analytical photogrammetry and by manual fieldwork. With regard to effectiveness and economy DSK started to evaluate new methods of data taking and data processing by using digital photogrammetry and remote sensing techniques.

INTRODUCTION

Deep hard coal mining activities lead to influences caused by subsidence movements. Therefore high demands on planning and monitoring are required as occurring effects may entail lasting changes and influences on the environment. To minimize those effects extensive environmental compatibility studies have to be performed and detailed prognosis have to be made.

Photogrammetric measurements and derivated high resolution DTM include fundamental information to register the current topographic situation and to detect subsidence movements over a period of time. These measurements done with analytical stereoplotters are highly accurate. However, manual measurement of DTM is time consuming and cumbersome. Besides the impact on infrastructure it is important to register effects on different types of land–use, forestry and on the ecological situation of biotopes. Today detailed field surveys are done gathering current information on land-cover and biotopes. With regard to the large area (1.500 sqkm) that has to be monitored manual field work is even time consuming. Together with auxiliary data, describing e.g. the ground-water situation, photogrammetric measure-ments and the digitized field data are part of the ”Geographic Information System” (GIS) set up by DSK. The dynamic mining activities demand to update the spatial information mentioned before at regular intervals. First investigations have been made by using multitemporal satellite-data. Due to the small-parcelled test area classifications of the broad-banded satellite-data were not adequate to map the land-cover mosaic and additional attributes with acceptable accuracy. To evaluate the advantages of digital photogrammetry and remote sensing DSK carried out research studies to use new data sets. Within the framework of these research activities a test area was recorded with the HRSC camera [1] in May 1998 and simultaneously with the HRSC and the HyMAP scanner [2] in August 1998. The first named sensor provides a very high geometric and the second a very high spectral resolution.

HYPERSPECTRAL SCANNER: HyMAP

The “whiskbroom” imaging spectrometer uses 128 bands collecting with narrow bands from the visible to the short-wave infrared and with broadband in the middle and the thermal infrared spectral regions [3]. The average bandwidth is nearly 16 nm, the radiometric resolution is 16 bit. The technical parameter (technical field of view to 60 degrees and 760 arrays per line) and the flown altitude of 3400 m results in a ground instantaneous field of view to 7 m. During the campaign an area with of 13 x 4 sqkm was covered with two overlapping strips. Coeval data recording on the ground included the use of a high resolution spectroradiometer (ASD FieldSpec FR) for measurements on selected reference targets. Figure 1 shows a subset of the test area.

The main emphasis on the current investigations is laid upon the recording of the current land-use on large scale and the determination of occurring changes resulting from mining activities. The goal is the creation of fundamentals and exemplary data layer for an environmental monitoring system which shall comprise the analysis of remote sensing data as an important constituent [5].

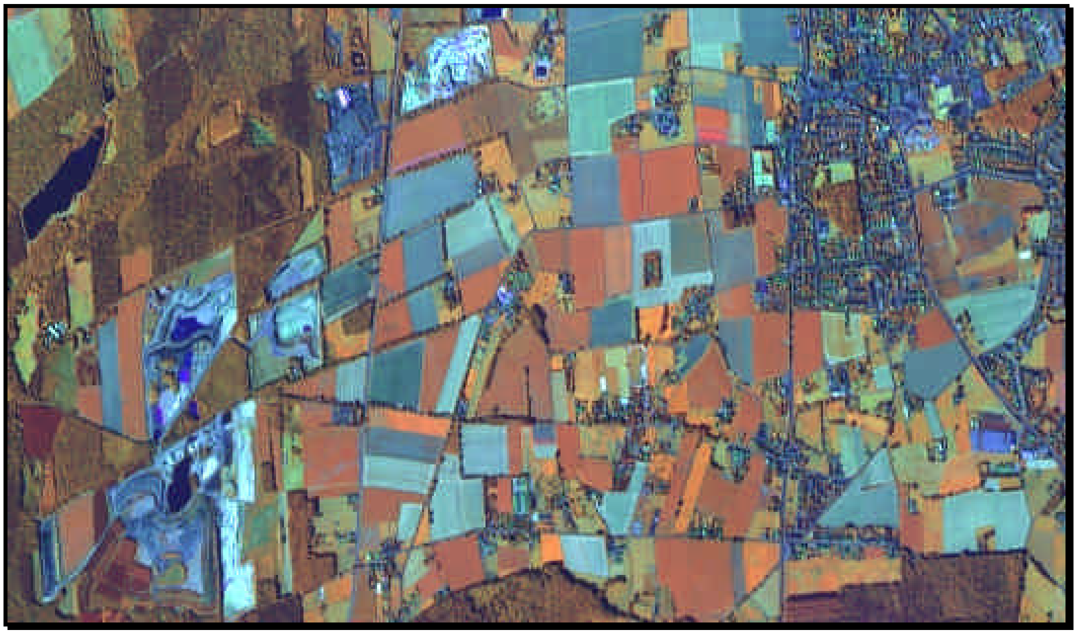

figure 1: detail of the test area (used channels: 28-84-16)

HIGH RESOLUTION STEREO-SCANNER: HRSC-A

The processing of the "Digital Elevation Model" (DEM) was done by the generation of five stereo-channels, which included two photometric channels to get redundant information of height data. The flown altitude leads to a ground pixel size of 15 cm. The accuracy in height of the HRSC was determined to 0,05 thousandth what results to ±20 cm [4]. A GPS-campaign was done in February 1999 to gather current ground-truth data of subsided areas. An area of 4 sqkm was recorded with 1800 points. With a point distance of 20 m sections with a total length of nearly 14 km along streets were measured. In addition a parking lot area of 4 acres was covered with a 5 m grid mesh (540 points). This place is totally covered by both HRSC-DEM and had already been recorded by an aerial flight in March 1993. The same points measured by GPS were re-measured on an analytical plotter using the photographs from 1993.

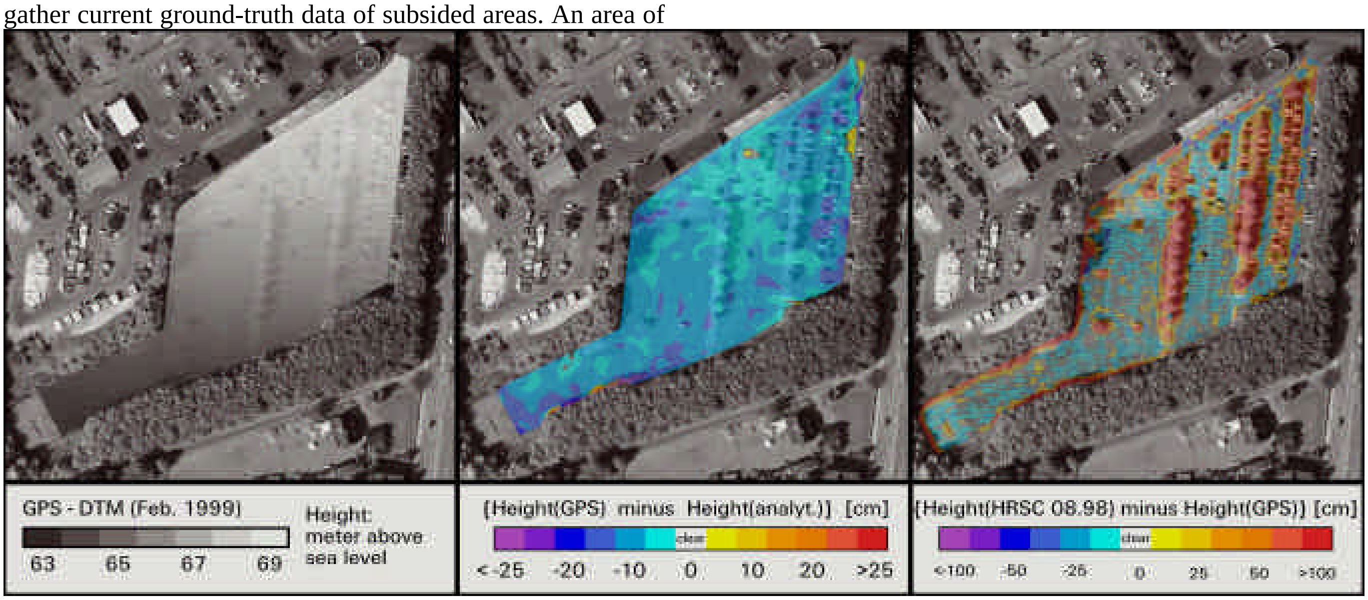

figure 2: DEM based on GPS-measurements 1999 (left), calculated differences between GPS-measurements and analytical measurements 1993 (middle), calculated differences HRSC-DEM and GPS-measurements

0-7803-5207-6/99/$10.00 (c) 1999 IEEE

Figure 2 shows the HRSC orthoimage from August 1998 and translucent the GPS-DEM (left), the differences between GPS-DEM and the analytical DEM (middle) and the differences of the HRSC-DEM (August 1998) and the GPS DEM (right). The comparison clearly indicates that the accuracy in height is nearly identical and within the precision of each used system. It can be seen that the differences between GPS based DEM and the analytical DEM show an offset of – 5 cm to –10 cm in the northern and up to –20 cm in the southern part. The amount of the differences indicates that the heights measured in 1999 are lower than in 1993. The distribution of the differences may indicate effects to the surface caused by underground mining activities. The right part of figure 2 shows the comparison of the HRSC-DEM and the GPS based DTM. Differences from 0 to –25 cm in steady areas and values in the range of the accuracy of the HRSC are calculated. Differences from 0 to +1 m can be found at parked cars and even in areas cast by shadows. Values greater than +1 m can be found at and near trees.
According to this the HRSC seems to be suitable for multitemporal surveys to detect underground mining subsidences. For rural areas first results of a comparison between May and August 1998 have shown the influence of the different growth stage of vegetation (see table 1).

table 1: height differences of vegetation (May - August)

vegetation cover	**calculated differences in height**
fallow fields	0 to –30 cm
Meadows, pasture	0 to +30 cm
Corn	-50 to –150 cm
coniferous woods	-50 to –80 cm
harvested grain fields	0 to +130 cm

These information may serve as auxiliary information for classifications based on the HyMAP.

DATA-FUSION

For first investigations a HSI transformation was used. The fused image owes the spatial resolution of the HRSC in combination with the spectral characteristics of the HyMAP data. This data set offers new information serving as a planning aid for visual interpretation and for classifications. Different type of forest as well as subtly differentiated conditions within a single agricultural field can be detected. Mixed pixel occur only at buildings and at the boundary lines of different land-cover. The use of this data instead of broad banded satellite data opens new possibilities for qualitative and quantitative analyses.

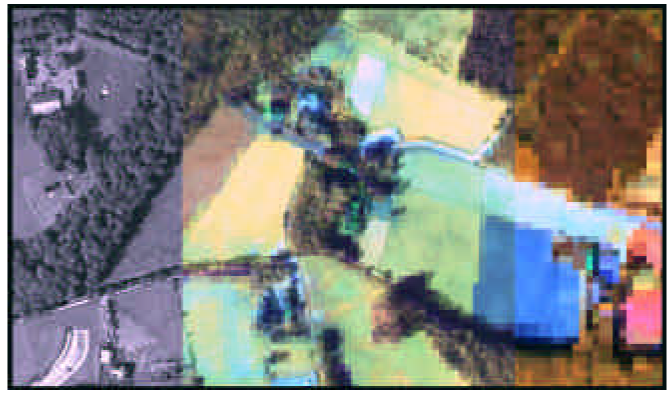

figure 3: detail of merged data from HRSC and HyMAP

CONCLUSION

An up-to-date surveillance is necessary to monitor effected areas and to update given predictions. The analysis of different airborne scanner data permits the generation of high resolution DEM and the derivation of current land-cover data. Utilizing multitemporal data analysis and integration of terrestrial data the determination on changes of the topographic situation can be performed. The results can be used to update the GIS.

ACKNOWLEDGMENT

This project is financed by DSK and supported by the German Aerospace Center (DLR) under contract 50EE9652. The ASD FieldSpec is courtesy of GeoFoschungszentrum Potsdam, DIV1 Remote Sensing. We like to thank G. Krüger and Dr. B. Rein for their help. We also thank E. Markus (Inst. of Mine Surveys) who guided the GPS measurements.

REFERENCES

[1]HRSC: DLR, URL: http://www.ba.dlr.de/ne/pe/HRSC-A/
[2]HyMAP: Integrated Spectronics, http://www.intspec.com/
[3]F. Lehman, T. Bucher, S. Hese, A. Hoffmann, S, Mayer, F. Oschütz and Y. Zhang, "Data Fusion of HyMAP Hyperspectral with HRSC-A Multispectral Stereo and DTM Data: Remote Sensing Data Validation and Application in Different Disciplines," in 1st EARSel Workshop on Imaging Spectroscopy, M. Schaepmann, D. Schläpfer and K. Itten, Eds. Paris: EARSeL, 1998, pp. 105-117
[4]F. Wevel, F. Scholten, G. Neukum and J. Albertz, "Digitale Luftbildaufnahme mit der HRSC – Ein Schritt in die Zukunft der Photogrammetrie," Photogrammetrie–Fernerkundung–Geoinformation (PFG), H. 6, 1998, pp. 337-348
[5]N, Benecke, S.Brandt, C. Fischer, V. Spreckels, P. Vosen, "Überwachung der Tagesoberfläche des Steinkohlen-tiefbaus," GIS – Journal for Spatial Information and Decision Making, Vol. 1 /99, 1999, pp. 34-39