Geophysical Research Abstracts
Vol. 13, EGU2011-1147, 2011
EGU General Assembly 2011

Detection and Quantification of Mining Subsidence in the Ruhr District (Germany) Using Historic Maps and Digital Elevation Models

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For the first time, an area-wide and large-scale calculation of differences in elevation between 1892 and today was conducted for the Ruhr District (Germany), a metropolitan region influenced by subsidence due to deep-seam coal mining starting in the middle of the 19th century.

In order to detect mining subsidence areas in the Ruhr District and to calculate the magnitude of mining subsidence, historical maps from 1892 with a scale of 1:25,000 were used to get the earliest possible area-wide data on surface elevation. Subsequently we compare it with current Digital Elevation Models and finally calculate the magnitude of differences in elevation. After georeferencing 22 historical maps in total, every contour line and each geodetic point were digitised on a scale of 1:3,000 with the help of a Geographic Information System (ArcGIS). The digitised data of contour lines and geodetic points was used to interpolate an elevation model by applying the Kriging algorithm and fitting an appropriate variogram model for every single map. For the same map a current Digital Elevation Model with a resolution of 10 m was used to interpolate the present surface. Finally, we intersect the two interpolated surfaces and calculated the differences in elevation.

As a result, the highest values of elevation differences, amounting to more than 25 m, were observed within the coal-fields of the former coal mine "Zollverein" which is distinguished for its long mining history and its World Heritage status. Two examples from the cities of Essen and Dortmund analysed in detail reveal that not only depressions but also elevation features are affected by mining subsidence. These kinds of surface transformations are not visible in the field without a comparison of digital topographical models. The change detections allow for a correlation with mining activities, because most of the mining subsidence areas are located next to a former coal mine. Furthermore, tectonic features of the Carboniferous strata are reflected by the location of subsidence areas, since they are located along synclines with a gentle dip of coal seams or confined by the location of predominant faults. The average amount of a net surface lowering was calculated for all maps digitised and analysed, resulting in a maximum value of 5.16 m for the map of Gelsenkirchen within the central Ruhr District with a total area of 128.5 sqkm. The average net surface lowering of the total area under investigation (approximately 2,800 sqkm) amounts to 1.55 m.

The presented results of differences in elevation are primarily based on the method of digitising contour lines and elevation points in historical maps of the Ruhr District. The accuracy of contour lines on the historical maps has to be questioned. Even if the levelling of individual survey points were accurate at that time, the drawing of contour lines might be faulty, especially after considering, that contour lines resulted from drawings on a plane survey sheet in the field with the scale of the original map (1:25,000). On the other hand, there is much evidence of a high level of accuracy in drawing the contour lines: The accuracy of interpolated elevation data from the historical maps can be estimated with the help of single levelling points measured by the land registry office of the Federal State “North Rhine-Westphalia”. The most helpful are 11 data series of levelling points starting in 1895. Only one series of those data shows a difference of more than 1 m between the measured surface elevation from 1895 and the interpolated surface elevation from 1892. All the others reveal a difference of less than 1 m.