Assessment of Subsidence and Riverbank Stability in Edmonton using X-band and C-band InSAR

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Summary

Interferometric Synthetic Aperture Radar (InSAR) has been used to measure ground deformation in the City of Edmonton. Potential sources of movement include residual subsidence over abandoned coal mines, subsidence due to ground compaction and/or fluid withdrawal, and gravitational movements of unstable slopes along the river valley. Both historic and modern images have been used to assess these movements.

Introduction

Edmonton, Canada, is cut by a broad, deep river valley. This valley exposes at least three Cretaceous coal seams. These coal seams are up to three metres thick, and stretch subhorizontally for many kilometers. Coal was mined in Edmonton from the 1870's until 1970. During this time, more than 13 million tonnes of coal were extracted from beneath the city. The easy accessibility of the coal along the valley sides led to the development of many mines beneath residential districts and the city centre.

The valley sides were already inherently unstable due to their morphology, the actions of the North Saskatchewan River, and the presence of clay layers. Their undermining due to coal extraction led to further instability. This was a result of changes to the local groundwater regime as well as the local mass balance.

Further from the valley walls, subsidence due to the room-and-pillar extraction method occurred. Residual subsidence may still continue to this day. In addition, there remains a danger of sudden collapse. Although we use the phrase 'sudden collapse,' such events are usually preceded by gradual subsidence. By identifying areas undergoing subsidence, and quantifying it, we can remediate this danger.

In this study, we have used historic SAR imagery from the European Space Agency's ERS satellites as well as current imagery from the German Space Agency's TerraSAR-X satellite to map ground movements in Edmonton. The C-band ERS imagery spans the time period from 1992 to 2000. The X-band TerraSAR-X imagery was acquired between April and November, 2009.

Theory and/or Method

An excellent overview of InSAR methods and applications can be found in Rocca, et al. (2000). In the last few years, a number of Persistent Scatterers Interferometry (PSI) algorithms have been developed, starting with the Permanent Scatterers technique (PSInSAR™; Ferretti et al., 2000). These algorithms utilize a long time series of SAR images to estimate movement of discrete, stable natural or artificial reflectors, with millimetric precision.

In this study, we computed all interferograms with a maximum baseline of 400 m and a maximum temporal separation of 4 years. For the TerraSAR-X images, this effectively meant all possible interferograms. The topographic contribution was removed using an existing digital elevation model. Based on the resulting InSAR pairs, we carried out the small-baseline subset (SBAS) processing steps as outlined in Berardino et al. (2002). For the ERS data, we applied a complex multi-look operation using two and eight looks in range and azimuth, respectively. The ground range pixel dimensions are therefore about 40 × 34 m in the range and azimuth directions, respectively. For the TerraSAR-X data, we applied a complex multi-look operation using two and four looks in range and azimuth, respectively. The ground range pixel dimensions are therefore about 5 m in both range and azimuth directions. In order to exclude decorrelated areas from the study, we selected only the common coherent pixels in all interferograms. Atmospheric contributions were estimated and filtered out before estimating a mean displacement velocity.

Conclusions

Initial assessment of historic ground movement in Edmonton was performed using ERS data from two overlapping tracks. Two significant areas of subsidence were identified; however, neither is associated with mining activity. The maximum rate of subsidence was approximately 3 mm/yr. The vegetated river valley provided little information due to the relatively large pixel size of the ERS images.

The much higher resolution and shorter repeat cycle of the TerraSAR-X satellite have led to a dramatic increase in data coverage. Small areas of infrastructure within the river valley, as well as paved road surfaces now allow analysis of ground deformation in that area. We present initial results from the processing of the TerraSAR-X imagery. The results are compared with those obtained using ERS imagery. We also present a preliminary interpretation of the measured deformation.

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