Paper Number: 1644

Potential of sinkhole precursor detection through interferometric SAR

Theron, A.[1, 2], Engelbrecht, J.[1] and Kemp, J.[2]

[1] Remote Sensing Research Unit, CSIR Meraka Institute, ATheron1@csir.co.za
[2] Department of Geography and Environmental Sciences, Stellenbosch University

Sinkholes are an unpredictable geohazard that endangers life and structures in susceptible areas globally. Subsidence sinkholes occur above cavernous bedrock comprised of highly soluble evaporates or calcium carbonates such as dolomite or limestone. Their formation requires the erosion of regolith material into cavities leading to the collapse of the roof strata. The cavity formation and subsequent erosion is mainly due to groundwater extraction or the ingress of water, often from leaking services or poor storm water drainage [1]. Although sinkholes generally appear catastrophically with little warning, the appearance of tension cracks, cracks in infrastructure and surface subsidence are often early signs of sinkhole development. Such precursory deformation occurs weeks to years before sinkhole formation due to underground cavity migration. These precursors are key to an operational early warning system and detecting them is currently a major challenge for sinkhole hazard mitigation efforts [2]. However, the location and timing of sinkholes is typically unpredictable. The *in situ* monitoring of large areas for small scale subsidence is therefore not feasible.

Satellite remote sensing, specifically Synthetic aperture radar (SAR), is a unique and promising tool for detecting sinkhole precursors. Interferometric SAR (InSAR) is an image processing technique able to frequently monitor large areas for millimetre scale deformation. InSAR has proven to be valuable and effective for many applications, from slope and ground deformation detection to infrastructure stability monitoring [3]. It is now being explored for sinkhole precursor detection with promising, though limited, results from various environments [4]. This includes encouraging initial results from a South African study presented in *fig 1*. However, sinkhole signatures are more challenging to isolate from error sources than larger scale deformation features. Advanced InSAR stacking methods can overcome some of these limitations and should therefore be explored further. Considerable work still needs to be done to determine the capabilities and limitations of InSAR as an operational warning system. Yet such a system will be valuable in mitigating sinkhole related damage.

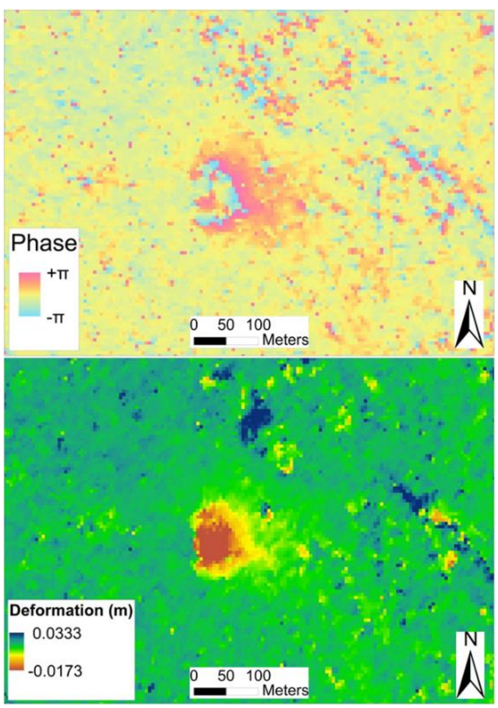

Figure 1: (Top) an interferogram showing the SAR phase change from acquisitions 11 days apart. A change in phase is directly related to a change in distance between the SAR and the ground. Imagery is from TerraSAR-X with a spatial resolution of 2.5m over Gauteng, South Africa in 2015. (Bottom) the resulting vertical displacement map showing ground deformation prior to sinkhole formation.

References:

[1] F. Gutierrez, M. Parise, J. De Waele, and H. Jourde, “A review on natural and human-induced geohazards and impacts in karst,” *Earth-Science Rev.*, vol. 138, pp. 61–88, 2014.

[2] M. Parise, D. Closson, F. Gutiérrez, and Z. Stevanović, “Anticipating and managing engineering problems in the complex karst environment,” *Environ. Earth Sci.*, vol. 74, no. 12, pp. 7823–7835, 2015.

[3] A. Ferretti, D. Colombo, A. Fumagalli, F. Novali, and A. Rucci, “InSAR data for monitoring land subsidence: time to think big,” *Proc. Int. Assoc. Hydrol. Sci.*, vol. 372, pp. 331–334, 2015.

[4] R. Nof, G. Baer, A. Ziv, Y. Eyal, E. Raz, S. Atzori, and S. Salvi, “Detection of sinkhole precursors along the Dead Sea , Israel by SAR interferometry,” vol. 15, p. 10699, 2013.

[2] M. Parise, D. Closson, F. Gutiérrez, and Z. Stevanović, “Anticipating and managing engineering problems in the complex karst environment,” *Environ. Earth Sci.*, vol. 74, no. 12, pp. 7823–7835, 2015.

[3] A. Ferretti, D. Colombo, A. Fumagalli, F. Novali, and A. Rucci, “InSAR data for monitoring land subsidence: time to think big,” *Proc. Int. Assoc. Hydrol. Sci.*, vol. 372, pp. 331–334, 2015.

[4] R. Nof, G. Baer, A. Ziv, Y. Eyal, E. Raz, S. Atzori, and S. Salvi, “Detection of sinkhole precursors along the Dead Sea , Israel by SAR interferometry,” vol. 15, p. 10699, 2013.

[1] F. Gutierrez, M. Parise, J. De Waele, and H. Jourde, “A review on natural and human-induced geohazards and impacts in karst,” *Earth-Science Rev.*, vol. 138, pp. 61–88, 2014.

[2] M. Parise, D. Closson, F. Gutiérrez, and Z. Stevanović, “Anticipating and managing engineering problems in the complex karst environment,” *Environ. Earth Sci.*, vol. 74, no. 12, pp. 7823–7835, 2015.

[3] A. Ferretti, D. Colombo, A. Fumagalli, F. Novali, and A. Rucci, “InSAR data for monitoring land subsidence: time to think big,” *Proc. Int. Assoc. Hydrol. Sci.*, vol. 372, pp. 331–334, 2015.

[4] R. Nof, G. Baer, A. Ziv, Y. Eyal, E. Raz, S. Atzori, and S. Salvi, “Detection of sinkhole precursors along the Dead Sea , Israel by SAR interferometry,” vol. 15, p. 10699, 2013.