15th International Congress of the Geological Society of Greece
Athens, 22-24 May, 2019 | Harokopio University of Athens, Greece
Bulletin of the Geological Society of Greece, Sp. Pub. **7** Ext. Abs. GSG2019-363

Monitoring Surface Deformation Combining Optical and Radar Sentinel Data: The New Zealand Case

E. Kalamatianou[1], C. Tourlakidis[1], A. Fylaktos[1], P. Krassakis[,2], I. Gougoustamos[1] I. Parcharidis[1]

(1) Harokopio University of Athens, El. Venizelou str.70, 17676 Kallithea, gp217306@hua.gr

(2) Centre for Research and Technology Hellas / Chemical Process and Energy, Resources Institute (CERTH/CPERI), Egialias str. 52, GR-151 25, Maroussi, Attica

The New Zealand region lies in the southwest Pacific Ocean overlapping a distinct belt of volcanic and earthquake activity that surrounds the Pacific Ocean. This is known as the "Ring of Fire". New Zealand lies on the boundary between the Pacific and Australian plates. To the north of New Zealand and beneath the eastern North Island, the thin and dense Pacific plate moves down beneath the thicker and lighter Australian plate. Within the South Island the plate margin is marked by the Alpine Fault where the plates are moved horizontally. Plate movement results in volcanic activity mainly in the North Island as well as earthquakes that are felt throughout the country (Graham, 2008). On November 14, 2016, a large magnitude [Mw] 7.8 earthquake struck the northeastern part of the South Island of New Zealand. The Kaikoura earthquake, named after the coastal town near the epicenter, had associated surface rupture on more than 20 mapped faults (Stirling et al. 2017), caused widespread crustal deformation (both uplift and subsidence), and triggered more than 10,000 landslides in the complex topography of the affected area (Dellow et al., 2017). Because of this, the earthquake has been described as the "most complex earthquake ever studied" (Jibson et al. 2018). Seismological evidence suggest that the main Kaikoura earthquake of Mw 7.8 was relatively rare for New Zealand with long recurrence intervals (Beavan et al. 2010).

Since the 1990's differential repeat-pass interferometry radar (DInSAR) based on SAR SLC images processing has proven an interesting tool for the measurement and observation of ground deformation (Massonnet and Rabaute., 1993). The basic idea of the method is the analysis of the phase of the reflected wave radar from two or more images which cover the same region in order to observe ground displacement. DInSAR has been widely used to identify ground deformation caused by different natural and anthropogenic phenomena. Many studies are motivated by the potential of SAR interferometry to be applied on a wide range of applications related to seismotectonics. The utilization of an appropriate interferometric dataset allows measuring the various components of the seismic cycle, namely the pre-seismic, co-seismic, and post-seismic deformation (Stramondo et al. 2009; Papanikolaou ei al. 2010, Briole et al. 2015).

Nevertheless, significant difficulties are found when using this technique. These difficulties are related to the large variability of slopes (steep and rough topography of prone areas), failure geometries, size of earthquake-prone areas and deformation rates causing phase ambiguity problems and signal decorrelation. Additionally, in regions with strong topographic relief presented local atmospheric variations can lead to strong atmospheric phase artifacts in many cases; all these parameters, often obstruct the interferometric pre-processing, making it difficult to estimate surface displacements (Hanssen 2001).

This paper aims to combine Sentinel SAR SLC and GRD images from Sentinel 1 satellite in order to overcome the above constrains of DInSAR. This is dome merging results about co-seismic displacement detection from SLC images and measurement from Sentinel 1 GRD data processing. There were used two images, one pre-seismic (Master) sensed on November3rd 2016 and one post-seismic (Slave) sensed on December 3rd 2016. Both SLC and GRD images were acquired on the same days, as the Level-1 Sentinel 1 products provide Single Look Complex images and Ground Range Detected images simultaneously. Level-1 focused data are the generally available products intended for most data users. Level-1 products can be either Single Look Complex (SLC) or Ground Range Detected (GRD). Each acquisition mode can potentially generate Level-1 SLC and GRD products. GRD resolutions will depend on the mode and the level of multi-looking. The SLC images were used in order to measure the displacement through the conventional interferometry technique (two passes plus DEM interferometry). The GRD images were used to enhance the results of the InSAR technique, which could not measure extreme surface displacement such as landslides. For that matter the Offset tracking method was used. Offset Tracking is a technique that measures feature motion between two images using patch intensity cross-correlation optimization. It is widely used in glacier motion estimation Level-1 Ground Range Detected (GRD) products consist of focused SAR data that has been detected, multi-looked and projected to ground range using an Earth ellipsoid model such as WGS84. The ellipsoid projection of the GRD products is corrected using the terrain height specified in the product general annotation. The terrain height used varies in azimuth but is constant in range (Lu & Veci, 2016). All referred methods were done with SNAP, the open source software for SAR image processing provided by ESA.

In order to combine the results of both methods a supervised classification was done in ArcGIS software provided by ESRI. The InSAR technique provides displacement results in millimeters, but the Offset-tracking technique provides results in millimeters per day, so we processed the latter results so they have the same units with displacement. All results were combined in one readable map to provide the total displacement of the affected area in Kaikoura.

References

Barrell, DJA, Litchfield, NJ, Townsend, DB, Quigley, M, Van Dissen, RJ, Cosgrove, R, Cox, SC, Furlong, K, Villamor, P, Begg, JG, Hemmings-Sykes, S, Jongens, R, Mackenzie, H, Noble, D, Stahl, T, Bilderback, E, Duffy, B, Henham, H. Klahn, A, Lang, EMW, Moody, L, Nicol, R, Pedley, K and Smith, A. 2011. Photographic Feature–Strike-slip ground surface rupture (Greendale Fault) associated with the 4 September 2010 Darfield earthquake, Canterbury, New Zealand. Quarterly Journal of Engineering Geology and Hydrogeology, 44: 283–291.

Briole, P., Elias, P., Parcharidis, I., Bignami, C., Benekos, G., Samsonov, S., Kyriakopoulos, C., Stramondo, S., Chamot-Rooke, N., Drakatou, M.L. & Drakatos, G., (2015). The seismic sequence of January-February 2014 at Cephalonia Island (Greece): constraints from SAR interferometry and GPS, Geophysical Journal International., 203, 1528-1540.

Dellow S. et al., (2017) Bulletin of the New Zealand Society for Earthquake Engineering, Vol. 50, No. 2, 106-116

Dowrick, DJ. 1998. Damage and intensities in the magnitude 7.8 1931 Hawkes Bay, New Zealand, earthquake. Bulletin of the New Zealand Society for Earthquake Engineering, 31: 139–163.

Graham, I.J. (ed.) 2008, A continent on the move: New Zealand: Geoscience into the 21st Century: Geological Society of New Zealand, Miscellaneous Publication, v. 124, pp. 1–388.

Hanssen, R.F. 2001 Radar interferometry: data interpretation and error analysis. In Remote Sensing and Digital Image Processing; Kluwer Academic: Dordrecht, Netherlands,

Jibson, R.W., Allstadt, K.E., Rengers, F.K., and Godt, J.W., (2018), Overview of the geologic effects of the November 14, 2016, Mw 7.8 Kaikoura, New Zealand, earthquake: U.S. Geological Survey Scientific Investigations Report 2017–5146, 39 p., https://doi.org/10.3133/sir20175146.

Lu J., Veci L., Sentinel 1 Toolbox, Offset Tracking Tutorial, Copyright © 2016 Array Systems Computing Inc. http://www.array.ca

Massonnet , D.; Rabaute, T. 1993 Radar interferometry: limits and potential. IEEE Trans. Geosci. Remot. Sen., 31, 455-464.

Papanikolaou, I.D., Foumelis, M., Parcharidis, I., Lekkas, E.L. &Fountoulis, I.G., (2010). Deformation pattern of the 6 and 7 of April 2009, Mw=6.3 and Mw=5.6 earthquakes in L' Aquila (Central Italy) revealed by ground and space based observations. Natural Hazards and Earth System Sciences 10, 73-87.

Quigley, M, Villamor, P, Furlong, K, Beavan, J, Van Dissen, R, Litchfield, N, Stahl, T, Duffy, B, Bilderback, E, Noble, D, Barrell, D, Jongens, R and Cox, S. 2010. Previously unknown fault shakes New Zealand's South Island. Eos, Transactions, American Geophysical Union, 91(49): 469–471.

Stirling, M.W. & Litchfield, Nicola & Villamor, Pilar & Van Dissen, Russ & Nicol, Andy & R. Pettinga, Jarg & Barnes, Philip & Langridge, Rob & Little, Tim & Barreil, D.J.A. & Mountjoy, Joshu & Ries, William & Rowland, J & Fenton, Clark & Hamling, I & Asher, Cameron & Barrier, Andrea & Benson, Adrian & Bischoff, Alan & Zinke, Robert. (2017). The Mw7.8 2016 Kaikōura earthquake: Surface fault rupture and seismic hazard context. Bulletin of the New Zealand Society for Earthquake Engineering. 50. 73-84.

Stramondo S, Chini M, Bignami C, Salvi S, Atzori S (2009) X-, C-, and L-Band DInSAR Investigation of the April 6. Abruzzi Earthq IEEE Geosci Remote S 8(1):49–53.