EGU21-11896
https://doi.org/10.5194/egusphere-egu21-11896
EGU General Assembly 2021

New 3D constraints on the co-seismic displacement field for the 1959 (M_w 7.2) Hebgen Lake earthquake from optical image correlation of historical aerial images

Lucia Andreuttiova[1], James Hollingsworth[2], Pieter Vermeesch[1], and Thomas Mitchell[1]
[1]University College London, Department of Earth Sciences, Gower Street, London WC1E 6BT, United Kingdom
[2]Univ. Grenoble Alpes, Univ. Savoie Mont Blanc, CNRS, IRD, IFSTTAR, ISTerre, 38000 Grenoble, France

Optical image correlation (OIC) is a powerful tool for measuring the 3-D near-field surface displacements produced in large earthquakes. The method compares pre- and post-earthquake orthorectified images; shifts between common pixels in the image pair reflects a 2-D (horizontal) offset. The third dimension (vertical displacement) is calculated by differencing the pre- and post-topography, while accounting for the horizontal displacements. Optical image correlation has a sub-pixel detection capability, and can provide information on the displacement field close to fault ruptures (where InSAR typically decorrelates). Small-scale measurements of the distributed damage provide important constraints on the strain distribution within the fault core and the surrounding damage zone, as well as offering insights into the rupture mechanics.

OIC is frequently applied to the recent earthquakes where the image footprint is large relative to the rupture extents. However, historical ruptures are documented by aerial photographs which cover a relatively small area. This means that many images are needed to cover the rupture area and all pixels in pre-and post-earthquake images which span the rupture are typically affected by the ground displacement. This creates complications for image co-registration, alignment and correlation of the final mosaics.

To address this problem we developed a workflow that automatically generates a DEM (digital elevation model) and an orthorectified image mosaic. The process uses structure-from-motion (SfM) and stereo-matching approaches, and results in precise and accurate registration between the image pairs.

We applied this method to the 1959 Hebgen Lake earthquake, SW Montana, U.S. This large (Mw 7.2) intraplate normal event re-activated pre-existing faults north of the Hebgen Lake reservoir and created a complex rupture network. We used 20 pre-earthquake photographs from 1947 and 70 post-earthquake images from 1977 and 1982. The final results show a 3-D displacement localized onto several prominent structures: the Hebgen fault and the Red Canyon fault, consistent with field mapping following the earthquake. A significant vertical offset and a large horizontal NS-component agree well with SW extension on NW-SE-striking normal faults. Additionally, we used fault-perpendicular profiles to explore the along-strike variation in fault displacement and to

determine the extent of the off-fault damage.

This work demonstrates that the application of OIC techniques to historical earthquakes can provide new information relating to the geometry and displacement of fault ruptures, and isolate the last event from the previously accumulated displacements. Additionally, the method we propose offers potential for the characterisation of historical earthquakes in general, and promises to improve our understanding of rupture behaviour through a statistical analysis of many earthquakes.