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High-resolution DEM generation from multiple remote sensing data sources for improved volcanic hazard assessment - a case study from Nevado del Ruiz, Colombia

Fanghui Deng (1), Timothy H. Dixon (1), Mel Rodgers (1,2), Sylvain J Charbonnier (1), Elisabeth A. Gallant (1), Nicholas Voss (1), Surui Xie (1), Rocco Malservisi (1), Milton Ordoñez (3), and Cristian M López (3)

(1) School of Geosciences, University of South Florida, Tampa, United States (fanghuideng@mail.usf.edu), (2) Department of Earth Sciences, University of Oxford, Oxford, United Kingdom, (3) Colombian Geological Service, Department of Geological Hazards, Manizales, Colombia

Eruptions of active volcanoes in the presence of snow and ice can cause dangerous floods, avalanches and lahars, threatening millions of people living close to such volcanoes. Colombia's deadliest volcanic hazard in recorded history was caused by Nevado del Ruiz Volcano. On November 13, 1985, a relatively small eruption triggered enormous lahars, killing over 23,000 people in the city of Armero and 2,000 people in the town of Chinchina. Meltwater from a glacier capping the summit of the volcano was the main contributor to the lahars. From 2010 to present, increased seismicity, surface deformation, ash plumes and gas emissions have been observed at Nevado del Ruiz. The DEM is a key parameter for accurate prediction of the pathways of lava flows, pyroclastic flows, and lahars. While satellite coverage has greatly improved the quality of DEMs around the world, volcanoes remain a challenging target because of extremely rugged terrain with steep slopes and deeply cut valleys. In this study, three types of remote sensing data sources with different spatial scales (satellite radar interferometry, terrestrial radar interferometry (TRI), and structure from motion (SfM)) were combined to generate a high resolution DEM (10 m) of Nevado del Ruiz. 1) Synthetic aperture radar (SAR) images acquired by TSX/TDX satellites were applied to generate DEM covering most of the study area. To reduce the effect of geometric distortion inherited from SAR images, TSX/TDX DEMs from ascending and descending orbits were merged to generate a 10×10 m DEM. 2) TRI is a technique that uses a scanning radar to measure the amplitude and phase of a backscattered microwave signal. It provides a more flexible and reliable way to generate DEMs in steep-slope terrain compared with TSX/TDX satellites. The TRI was mounted at four different locations to image the upper slopes of the volcano. A DEM with 5×5 m resolution was generated by TRI. 3) SfM provides an alternative for shadow zones in both TSX/TDX and TRI images. It is a low-cost and effective method to generate high-quality DEMs in relatively small spatial scales. More than 2000 photos were combined to create a DEM of the deep valley in the shadow zones. DEMs from the above three remote sensing data sources were merged into a final DEM with 10×10 m resolution. The effect of this improved DEM on hazard assessment can be evaluated using numerical flow models.