The sensitivity of a volcanic flow model to digital elevation models from diverse sources

NF Stevens[1*], V Manville[2] and DW Heron[1]

[1]Institute of Geological and Nuclear Sciences, Gracefield Research Center, PO Box 30368, Lower Hutt, New Zealand
[2]Institute of Geological and Nuclear Sciences, Wairakei Research Center, Private Bag 2000, Taupo, New Zealand
[*corresponding author, n.stevens@gns.cri.nz]

Rationale:
Past volcanic activity at Ruapehu and Tongariro, North Island, New Zealand, has included the generation of pyroclastic flows, block and ash flows, lava flows and lahars (e.g. Palmer & Neall, 1989). These phenomena present a real future risk in this area. Volcanic flows are influenced by topography, and in the past, areas vulnerable to such hazards were identified using contour maps, combined with field mapping of the deposits of previous eruptions.

A growing trend is the use of computerized flow models to predict potential areas of devastation. These aim to improve the speed and objectivity of risk assessment. The accuracy of these computer models depends on two factors, the nature and veracity of the flow model itself, and the accuracy of the topographic data set over which it is run. Accurate, up-to-date topographic data are therefore invaluable for risk assessment at volcanoes. However, to date, little work has been done to assess the sensitivity of the output of these models to DEM quality.

All digital elevation models (DEMs) contain innate errors. The nature of these errors depends on the accuracy of the original measurements of the terrain, and on the method used to build the DEM. In this study, we investigate the effect that DEM quality has on the performance of a volcanic flow model designed to delineate areas at risk from lahar inundation.

Data availability:
The Tongariro Volcanic Center is unusual by New Zealand standards because 2 sets of digital topographic data of the area were available. These are derived from (1) digitized 1:50,000 contour maps published by Land Information New Zealand (LINZ), and (2) airborne C-band synthetic aperture radar interferometry obtained using the NASA AIRSAR system during the 1996 and 2000 PACRIM missions. The AIRSAR data have a vastly superior accuracy (10 m spatial resolution, 1-2 m vertical resolution).

Methodology:
We used the volcanic flow model LAHARZ, which was developed at the USGS for model debris avalanches from sector collapse and associated long run-out lahars (Schilling 1998) and was made available to us via collaboration. The aim was not to test the efficacy of the model, but the effect of DEM quality on the model. The LAHARZ model first calculates flow paths across the DEM. An area of inundation is then calculated for a user-specified flow path and deposit volume.

The southern Ruapehu area was chosen as the site over which to run the model. This area was ideal because (1) both DEMs cover a significant length of the river catchments, (2) the area includes the steeper slopes of the volcano flanks and the relatively flatter slopes of the surrounding ringplain of reworked deposits, (3) data loss in river channels in the AIRSAR data due to shadowing are minimal, and (4) the risk assessment issues in the area at the time of writing are not politically sensitive, unlike other areas of the volcano.

Results:

The results of our study are described in detail in Stevens et al. (2002). In the parts of the DEM corresponding to the steeper slopes (>4 degrees) of the volcano flanks, the model was in good agreement for both DEMs. This is most likely because the river channels are more likely to be incised deeply, and flow paths predicted by the model are generally in agreement for both DEMs despite the differing nature of the source data.

Over the shallow slopes of the volcano ring plain (~<4°), where channels are less deep and are more likely to meander, problems were encountered with flow path prediction in both DEMs. These were due to interpolation errors in the DEM derived from 1:50K contours, and due to the edges of commercial forestry blocks apparent in the AIRSAR DEM. The errors in flow path derivation mostly resulted in false flow paths running perpendicular to the actual rivers, which would result in a predicted flow inundating a completely different region. The predicted lateral and longitudinal extent of deposit inundation was also sensitive to the type of DEM used, most likely in response to the differing degrees of surface texture preserved in the DEMs.

The majority of the local population and infrastructure in the area is sited on the ring plain, so it is important to improve the reliability of model predictions in this area. We developed a technique to refine contour-derived DEMs and reduce the error in predicted flow paths, using digitized stream paths as breaklines to constrain the contour interpolation. This improved flow path prediction.

The suitability of forthcoming topographic measurements acquired by the NASA Shuttle Radar Topography Mission (SRTM) was also tested. Resampling the AIRSAR DEM to 90 m and 30 m pixels to simulate SRTM Level 1 and 2 resolution had negligible effect on the LAHARZ flow model, other than decreasing the processing time dramatically, showing that SRTM data will be an asset to volcanic flow modeling. However, volcanoes are inherently dynamic systems, and vertical elevation changes in the order of tens of meters are not unusual. The SRTM data will therefore provide a baseline topographic dataset, which will need to be updated for realistic risk assessment following significant volcanic topographic changes. Such updates could feasibly be maintained by an airborne system, such as the NASA AIRSAR interferometric radar.

References:

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