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Automated recognition of quasi-planar ignimbrite sheets and paleo-surfaces via robust segmentation of DTM – examples from the Western Cordillera of the Central Andes

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The Western slope of the Central Andes between 22° and 17°S is characterized by large, quasi-planar landforms with tilted ignimbrite surfaces and overlying younger sedimentary deposits (e.g. Nazca, Oxaya, Huaylillas ignimbrites). These surfaces were only modified by tectonic uplift and tilting of the Western Cordillera preserving minor now fossilized drainage systems. Several deep, canyons started to form from about 5 Ma ago. Due to tectonic oversteepening in a arid region of very low erosion rates, gravitational collapses and landslides additionally modified the Andean slope and valley flanks. Large areas of fossil surfaces, however, remain. The age of these surfaces has been dated between 11 Ma and 25 Ma at elevations of 3500 m in the Precordillera and at c. 1000 m near the coast. Due to their excellent preservation, our aim is to identify, delineate, and reconstruct these original ignimbrite and sediment surfaces via a sophisticated evaluation of SRTM DEMs.

The technique we use here is a robust morphological segmentation method that is insensitive to a certain amount of outliers, even if they are spatially correlated. This paves the way to identify common local planar features and combine these into larger areas of a particular surface segment. Erosional dissection and faulting, tilting and folding define subdomains, and thus the original quasi-planar surfaces are modified. Additional processes may create younger surfaces, such as sedimentary floodplains and salt pans. The procedure is tuned to provide a distinction of these features.

The technique is based on the evaluation of local normal vectors (perpendicular to the actual surface) that are obtained by determination of locally fitting planes. Then, this initial set of normal vectors are gradually classified into groups with similar properties providing candidate point clouds that are quasi co-planar. The quasi co-planar sets of points are analysed further against other criteria, such as number of minimum points, maximized standard deviation of spatial scatter, maximum point-to-plane surface, etc.

SRTM DEMs of selected areas of the Western slope of the Central Andes have been processed with various parameter sets. The resulting domain structure shows strong correlation with tectonic features (e.g. faulting) and younger depositional surfaces whereas other segmentation features appear or disappear depending on parameters of the analysis. For example, a fine segmentation results – for a given study area – in ca. 2500 planar features (of course not all are geologically meaningful), whereas a more meaningful result has an order of magnitude less planes, ca. 270. The latter segmentation still covers the key areas, and the dissecting features (e.g., large incised canyons) are typically identified. For the fine segmentation version an area of 3863 km^2 is covered by fitted planes for the ignimbrite surfaces, whereas for the more robust segmentation this area is 2555 km^2. The same values for the sedimentary surfaces are 3162 km^2 and 2080 km^2, respectively. The total processed area was 14498 km^2. As the previous numbers and the 18,1% and 18,6% decrease in the coverage suggest, the robust segmentation remains meaningful for large parts of the area while the number of planar features decreased by an order of magnitude. This result also emphasizes the importance of the initial parameters.

To verify the results in more detail, residuals (difference between measured and modelled elevation) are also evaluated, and the results are fed back to the segmentation procedure. Steeper landscapes (young volcanic edifices) are clearly separated from higher-order (long-wavelength) structures. This method allows to quantitatively identify uniform surface segments and to relate these to geologically and morphologically meaningful parameters (type of depositional surface, rock type, surface age).