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Elevation validation and geomorphic metric comparison with focus on ASTER GDEM2, SRTM- C, ALOS World 3D, and TanDEM-X

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Geomorphologists use digital elevation models (DEMs) to quantify changes in topography – often without rigorous accuracy assessments. In this study we validate and compare elevation accuracy and derived geomorphic metrics from the current generation of satellite-derived DEMs on the southern Central Andean Plateau. The average elevation of 3.7 km, diverse topography and relief, lack of vegetation, and clear skies create ideal conditions for remote sensing in this study area. DEMs at resolutions of 5-30 m are sourced from open-access, research agreement, and commercial outlets, with a focus on the 30 m SRTM-C, 30 m ASTER GDEM2, 12 m TanDEM-X, and 5 m ALOS World 3D data. In addition to these edited products, manually generated DEMs included 10 m single-CoSSC TerraSAR-X / TanDEM-X DEMs and a 30 m stacked ASTER L1A stereopair DEM. We assessed vertical accuracy by comparing standard deviations (SD) of the DEM elevation versus 307,509 differential GPS (dGPS) measurements with < 0.5 m vertical accuracy, acquired across 4,000 m of elevation. Vertical SD was 3.33 m, 9.48 m, 6.93 m, 1.97 m, 2.02-3.83 m, and 1.64 m for the 30 m SRTM-C, 30 m ASTER GDEM2, 30 m stacked ASTER, 12 m TanDEM-X, 10 m single-CoSSC TerraSAR-X / TanDEM-X DEMs, and 5 m ALOS World 3D, respectively. Analysis of vertical uncertainty with respect to terrain elevation, slope, and aspect revealed the high performance across these attributes of the 30 m SRTM-C, 12 m TanDEM-X, and 5 m ALOS World 3D DEMs. The 10 m single-CoSSC TerraSAR-X / TanDEM-X DEMs and the 30 m ASTER GDEM2 displayed slight aspect biases, which were removed in their stacked counterparts (TanDEM-X and the stacked ASTER DEMs). We selected the high quality 30 m SRTM-C, 12 m TanDEM-X, and 5 m ALOS World 3D for geomorphic metric comparison in a 66 sqkm catchment with a clear river knickpoint. For trunk channel profiles analyzed with chi plots, consistent m/n values of 0.49-0.57 were found regardless of DEM resolution or SD. Hillslopes were analyzed upstream and downstream of the knickpoint by calculating slope and curvature distributions and plotting slope, curvature, and drainage area to assess the hillslope-to-valley transition. While slope and hillslope length measurements vary little between datasets, curvature displays higher magnitude measurements with fining resolution. To assess DEM noise and periodicity in the landscape we employed a Fourier analysis to identify DEM frequencies and their spectral power. The optical 5 m ALOS World 3D DEM shows high-frequency noise in 2-8 pixel steps, with no corresponding landscape features in this highly diffusive, vegetation-free environment. Finally, we explore the geomorphometric potential of the higher-quality 12 m TanDEM-X DEM through a hillslope length and surface roughness assessment across steep environmental, climatic and topographic gradients in the Quebrada del Toro catchment, west of Salta, Argentina.