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Decadal rates and spatial distribution of gravel-bed river aggradation and incision from spaceborne DEMs: Applications in the Northwest Argentine Andes

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As sediment and nutrients are delivered to trunk channels as boulders, gravels, sands, and silts via hillslope processes like landslides and weathering, the network transports material downstream and out to continental drainage systems. Influenced by tectonics, weather, climate, biota, and human tampering, the rates and patterns of river-bed erosion and deposition are known to change through time, often on human-relevant time scales. Previous work tackling river-bed height change relied on historical records and spatially sparse, but detailed, cross sections. More recently, studies have utilized 1-km reach repeat measurements at meter to centimeter resolution from total station surveys, lidar, or drones equipped with cameras for structure from motion processing. For the first time, we leverage coarser (~30 m resolution) spaceborne datasets to measure 15 years of gravel-bed river height changes between the SRTM-C DEM collected in February 2000 and the TanDEM-X DEM completed in 2015. These data provide spatially continuous gridded measurement in over 600 km of channels draining three 4000–25,000 km^2 catchments from the margin of the internally drained Central Andean Plateau to the populated foreland in the Northwest Argentine Andes.

Careful DEM co-registration rectified ~1/15 pixel (~2 m) east-west and north-south directed shifts, manifested in a slope-dependent aspect bias, in addition to a mean vertical shift of ~2 m. Robust z-scoring was employed on co-registered DEMs to extract meaningful height differences in the gravel-bed trunk channels. From the 15-year time difference we are able to measure vertical rates of change down to $\pm$ 0.32 m/y under best conditions (4.8 m of height change), while locally rates are found as high as $\pm$ 0.5–1 m/y (7.5–15 m height change). These aggrading or incising reaches are spatially variable, however are often continuous over ~5-km lengths. The highest rates of incision correspond to over-steepened reaches and narrow bedrock gorges with high specific stream power, and also to arid upstream regions where unconsolidated sediment is mobilized during impinging hydrometeorologic events. Naturally aggrading reaches are found where large tributaries or alluvial fan deposits enter the trunk channels, and also in upstream areas with higher precipitation where unconsolidated hillslope and tributary sediments are delivered to the channel. Anthropogenic aggradation is found upstream of dams and reservoirs and also where gravel mining creates large piles of material. Although we lack measurements in the narrow headwaters (below measureable limit for SRTM-C), the mass balances of the measured channel sections indicates high variability, though near steady state, of the upstream reaches. Downstream, where channels are influenced by compounding effects and anthropogenic tampering, we measure aggradation directly upstream of dams and reservoirs and in regions with gravel mining of ~2.5–5 $\times$ 10^4 m^3/y, leading to overall ~500,000 m^3 of gravel accumulation over the 15 years. We conclude that the impact of tectonic forcing of gravel-bed river transport can be managed by careful, long-term planning, however rapid and unexpected changes on shorter time-scales associated with dams, gravel mining, and climate change require drastic measures to maintain infrastructure.