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Mapping hillslope to fluvial transitions in arid and semi-arid mountain landscapes with TerraSAR-X and Sentinel-1 synthetic aperture radar

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Erosion in mountain landscapes occurs in the hillslope and fluvial domains. These domains are characterized by fundamentally different processes in space and time and have correspondingly different impacts on the landscape. The transition from hillslope to fluvial erosional processes depends on several factors, including local geology, climate, and environment. However, pinpointing where these transitions occur can prove challenging and is limited by the quality and availability of data and observations for a given region. We propose a method that exploits synthetic aperture radar (SAR) interferometric coherence from the Sentinel-1 and TerraSAR-X missions and the high-resolution 12-m TanDEM-X DEM to identify transitions between hillslope, fluvial, and alluvial erosional regimes in arid and semi-arid landscapes. Our study focuses on two large (∼103 km2) basins the south-central Andes in northwestern Argentina; one semi-arid intermontane basin and one arid, high-altitude interior basin. These regions experience marked seasonal change with distinct wet and dry seasons and are characterized by little to no vegetation cover.

The coherence between two SAR images is sensitive both to changes in phase (e.g., elevation at the mm scale in satellite line-of-sight) and amplitude (e.g., reflective magnitude determined by surface cover or roughness). Coherence loss – in the absence of vegetation and anthropogenic factors – should therefore result from surficial processes such as landsliding, hillslope slump, fluvial cobble movement, or alluvial sediment transport. Sentinel-1 SAR C-band (5 x 20 m) data for this region is available from mid-2014 with a return time of 2-6 weeks. Using approximately two years of Sentinel-1 data, we construct ascending- and descending-track timeseries of coherence that covers multiple wet and dry seasons for each region. Additionally, we have acquired approximately 1 year of TerraSAR-X X-band (1.2 x 3.3 m) SAR data for the arid, interior basin. These timeseries are temporally averaged to create yearly and seasonal coherence maps.

Based on our coherence timeseries, we observe strongly seasonal coherence loss in the semi-arid, intermontane basin, particularly on hillslopes, where the wet-dry seasonality is more pronounced. Hillslope coherence loss is spatially discrete and clusters on critical hillslopes, suggesting that coherence loss corresponds to landsliding or reactivation of landslide scars and/or scree slopes. However, we do not observe a strong seasonal signal in the arid, high-elevation basin, where high winter winds can cause sediment movement during the dry season. We calculate drainage area based on the TanDEM-X 12-m DEM and observe two distinct transitions in coherence as drainage area increases: (1) A hillslope-to-fluvial transition represented by a significant decrease in the range of coherence values and moderate decrease in median coherence. (2) A fluvial-to-alluvial transition represented by a marked decrease in median coherence and a corresponding increase in coherence range. We therefore propose that coherence loss can be used as a proxy for surface sediment movement in hillslope, fluvial, and alluvial settings and provide valuable insight into where these processes transition across a landscape.