Sentinel-1 synthetic aperture radar coherence for erosion mapping in arid and semi-arid environments

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Abstract

Erosion in mountain landscapes is comprised of hillslope and fluvial processes that remove and transport sediment. These processes act by fundamentally different methods 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 Sentinel-1 synthetic aperture radar (SAR) interferometric coherence 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. The coherence between two SAR images is sensitive both to changes in phase and amplitude and should therefore result from surficial processes such as landsliding, hillslope slump, fluvial cobble movement, or alluvial sediment transport. We construct a Sentinel-1 coherence timeseries for arid and semi-arid regions of the Argentinian Central Andes that covers multiple wet and dry seasons for each region. Based on our coherence timeseries, we observe strongly seasonal coherence loss in the semi-arid basin, particularly on hillslopes, where the wet-dry seasonality is more pronounced. Hillslope coherence loss is spatially discrete and clusters on supercritical slopes, 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 basins, where winter high winds can cause sediment movement during the dry season. We compare the temporally averaged coherence maps to the high-resolution TanDEM-X 12-m DEM and observe two distinct transitions in coherence as a function of increasing drainage area: (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.

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