Synthetic aperture radar coherence as a proxy for geomorphic activity

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Mountain landscapes are shaped by hillslope and fluvial processes that remove and transport material and sediment. Developing proxies to map these processes through space and time is a key element in better understanding their distribution and drivers. Remotely sensed and satellite observations of Earth's surface are greatly expanding the reach of geomorphologists and presenting a myriad of new opportunities to explore and quantify Earth surface processes. Synthetic aperture radar (SAR), in particular, promises to be a powerful tool for mapping and quantifying geomorphic processes. Here, we exploit a time series of coherence estimates between SAR images from the Copernicus Sentinel-1 mission. Coherence is the spatial correlation between two SAR images and is sensitive to changes in both the phase (elevation) and amplitude (surface backscatter) of the received radar signal. Geomorphic processes such as landsliding, hillslope slump, cobble movement, or alluvial sediment transport can result in loss of SAR coherence. In regions without significant vegetation or anthropomorphic input, we therefore propose that coherence loss is a proxy for surface sediment movement and geomorphic activity. We constructed time series of Sentinel-1 coherence images spanning three to five years for arid and semi-arid regions of the Argentinian Central Andes and the north-western Himalaya. Both regions are characterized by active tectonics and seasonal climatic gradients. The relatively short revisit time of the Sentinel-1 satellites (~2-4 weeks in our regions of interest) mean that we can not only map geomorphic activity averaged over multiple years, but observe intra-annual and seasonal differences throughout a given year. We are also able to compare interannual geomorphic responses during years with, e.g., relatively strong or weak monsoon seasons.

We couple our Sentinel-1 coherence time series with a compilation of published 10-Berrylium terrestrial cosmogenic nuclide basin-wide denudation rates from the Open Cosmogenic isoTOPe and UmineScence (OCTOPUS) database. For basins with cosmogenic data, we derive temporal and spatial statistics of our coherence time series. Across regional gradients, the range of coherence within basins positively correlates to millennial denudation rates and to topographic metrics used to indicate long-term uplift (e.g., channel steepness). Outlying basins include those in which erosion is driven by large, deep-seeded landslides that occur over repeat times longer than our multi-year observation period. Our study suggests that a dense time series of interferometric coherence can be used as a proxy for surface sediment movement and landscape stability in
vegetation-free settings at event to decadal timescales.