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Scaling behavior of lidar-derived snow depth across the semi-arid Chilean Andes

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The seasonal melt of mountain snow-cover provides a vital source of freshwater for downstream systems, sustaining multiple productive uses, population needs, and unique ecosystems. In the semi-arid Andes Cordillera, the snowpack acts as a natural water reservoir, releasing spring snowmelt runoff that accounts for more than 60 % of the total annual streamflow. Hence, understanding and characterizing the spatial variability of snow over this large domain is critical for accurate hydrological predictions. We examine the probability density functions and the geostatistical structure of snow depth through variogram analysis, using terrestrial lidar scans acquired during two seasons (2018 and 2019). First, we compare the spatial patterns of snow depth near maximum accumulation at three experimental sites: (i) the Tascadero catchment (-31.26°N, 3270-3790 m a.s.l.), (ii) the Las Bayas experimental catchment (-33.31°N, 3218-4022 m a.s.l.); and (iii) the Valle Hermoso catchment (-36.91°N, 1449-2563 m a.s.l.). Second, we analyze the inter- and intra-annual variability of snow depth patterns in the Las Bayas catchment, where seven scans were acquired during seasons 2018 and 2019.

The comparison across sites reveals snow depth fractal behavior until a first omnidirectional scale break in the range 15-22 m for unvegetated areas, and a short-range fractal dimension spanning 2.5-2.65. In the woodland of Valle Hermoso, a much shorter (5 m) scale break and a larger short-range fractal dimension (2.73) are found. Secondary scale ranges and breaks spanning 62-125 m are found in all sites but Tascadero, where snow depth follows a bimodal distribution across the domain. In the Las Bayas domain, inter-annual consistency is found in snow scaling patterns, with two distinct regions separated by a short scale break ~6 m early in the winter, increasing to larger break lengths (15-18 m) in July and August. These results help to inform about the appropriate spatial configuration for snowpack modeling across the Andes. Efforts to better understand the modulation of topography (slope and wind exposure) and vegetation on snow depth distribution patterns, as well as impacts of dominant wind directions on anisotropies in fractal parameters, are ongoing.