Submitted Abstract

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Abstract

The resilience of mountain forests is a critical concern for forest management in the Alps, since disturbances can jeopardize forests' capacity to provide essential ecosystem services, such as protection from natural hazards. In recent years, significant progress has been made in observing changes in canopy cover at the large scale, including forest disturbances and recovery, from optical satellites. However, optical satellites have a limited capacity to detect changes in forests' three-dimensional structure, including properties such as stand height, leaf area, biomass, and vertical heterogeneity. These structural characteristics play an important role in determining forests' resilience and their capacity to provide ecosystem services. So far, assessments of forest structure have mostly relied on airborne LiDAR data, which is not available consistently at large scales, limiting the potential for Alpine-scale analyses. In this study, we use data from GEDI, NASA's recently launched spaceborne LiDAR mission, to assess the structural characteristics of Alpine forests. We combine plot-level GEDI data with a Landsat-based disturbance map, which allows for a space-for-time analysis of forest recovery after disturbances. Across the Alps, undisturbed forests show a similar distribution of forest structure, with two main basins of attraction in open and closed forests. Disturbances cause a shift towards open forest structures, with the lowest point of canopy cover and stand height often occurring around 10 years after a disturbance. This is followed by recovery, with consistent recovery patterns across different forest types. After 30 years, most disturbed forests regain much of their protective function, although they still show differences in structure compared to undisturbed forests. We discuss how such large-scale analyses can contribute to our understanding of forest resilience, as well as the challenges and limitations of using spaceborne LiDAR in complex mountain terrain.