Mapping snow depth in open alpine terrain from stereo satellite imagery

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Abstract. To date, there is no definitive approach to map snow depth in mountainous areas from spaceborne sensors. Here, we examine the potential of very-high-resolution (VHR) optical stereo satellites to this purpose. Two triplets of 0.70 m-resolution images were acquired by the Pléiades satellite over an open alpine catchment (14.5 km^2) under snow-free and snow-covered conditions. The open-source software Ame's Stereo Pipeline (ASP) was used to match the stereo pairs without ground control points, to generate raw photogrammetric clouds and to convert them into high-resolution Digital Elevation Models (DEMs) at 1-m, 2-m, and 4-m resolutions. The DEMs differences (dDEMs) were computed after 3D-coregistration, including a correction of a $-0.48\,\mathrm{m}$ vertical bias. The bias-corrected dDEMs maps were compared to 451 snow probe measurements. The results show a decimetric accuracy and precision in the Pléiades-derived snow depths. The median of the residuals is $-0.16\,\mathrm{m}$, with a standard deviation (SD) of 0.58 m at a pixel size of 2 m. We compared the 2 m-Pléiades dDEM to a 2 m-dDEM that was based on a winged unmanned aircraft vehicle (UAV) photogrammetric survey that was performed on the same winter date over a portion of the catchment (3.1 km^2). The UAV-derived snow depth map exhibits the same patterns as the Pléiades-derived snow map, and a median of -0.11 m and a SD of 0.62 m when compared to the snow probe measurements. The Pléiades images benefit from a very broad radiometric range (12 bits), allowing a high correlation success rate over the snow-covered areas. This study demonstrates the value of VHR stereo satellite imagery to map snow depth in remote mountainous areas even when no field data are available.