Satellite Stereo Snow Depth Retrievals over Complex Terrain

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December 27, 2022

Abstract

Fine-scale, sub-annual satellite stereo observations of snow cover and snow depth can help improve quantification of snow water equivalent at critical times during the accumulation and ablation season. We are refining very-high-resolution (VHR) spaceborne optical stereo methods to generate spatially-continuous digital surface models (DSMs) and maps of snow depth and snow water equivalent (SWE) over mountain sites in the Western U.S.

In this work, we leverage the open-source software of NASA's Ames Stereo Pipeline for extensive and iterative testing of stereogrammetric processing parameters to produce snow-free and snow-covered DSMs. Using open-source tools, we customize and improve automated surface co-registration using snow-free DSMs generated from spaceborne stereogrammetry and airborne lidar. High-resolution land cover classification maps derived from the input stereo images using machine learning methods improve the co-registration results and snow depth product quality.

We assess our stereo-derived DSM and snow depth mapping methods across multiple sites in Colorado using USGS 3D Elevation Program (3DEP) and the Airborne Snow Observatory (ASO) airborne lidar DSMs and snow depth products. We present initial evaluations of our surface elevation reconstructions across variable terrain and land cover. Finally, we use a bulk density approach and empirical density models to convert snow depth maps into maps of snow water equivalent.

We are developing a user-friendly notebook for the full workflow with default processing parameters tuned for mountain terrain. We hope that these tools will enable new users with limited photogrammetry experience to produce maps of snow depth and snow water equivalent from VHR satellite imagery.

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Key Takeaways

- Satellite stereo **snow depth maps resolve meter-scale** features and spatial distribution
- Intraseasonal and interannual snow depth retrievals over large areas ($> 1000 \text{ km}^2$)
- Automated workflow to generate snow depth time series without ground control

I. Introduction

Observations of snow depth are needed to **quantify** snow water equivalent at critical times of year.

We use

- WorldView-2 and WorldView-3 (WV)
- panchromatic satellite stereo images
- and snow-free airborne lidar data

To make

- digital elevation models (DEMs) and
- snow depth maps

Study area: Grand Mesa, CO



Above: Location of Grand Mesa, Colorado, USA with oblique aerial of the north arm. Photo credit: Chris Chickadel.

II. Approach

- 1. Generate DEMs for all pairwise combinations with NASA Ames Stereo Pipeline
- 2. Align multi-view stereo DEMs and create median DEM composites
- 3. Co-register composites with snow-off reference DEM using stable surfaces
- 4. Difference DEMs (dDEM = snow-on snow-free)
- 5. Compute statistics for snow using masks derived from multispectral images
- 6. Rejoice in snow depth map analysis!

References

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Acknowledgments

This work was financially supported by NASA grant #80NSSC18K1405. The WorldView Level-1B images used for this study are available under the NGA NextView/EnhancedView license. Resources supporting this work were provided by the NASA High-End Computing (HEC) Program through the NASA Advanced Supercomputing (NAS) Division at Ames Research Center. Many thanks owed to Oleg Alexandrov for his continued support provided by friends, loved ones, and members of the UW Terrain Analysis and *Cryosphere Observation Lab and the UW Mountain Hydrology Research group.*

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processing for DSM and DTMs, and our full Stereo2SWE workflow



