TOPOGRAPHIC CORRECTION OF SNOW ALBEDO MEASURED FROM A UAV

Andrew Mullen[1], Eric A. Sproles [1,2], Jordy Hendrikx[1], Joseph A. Shaw[3], and Charles Gatebe[4]

EXTENDED ABSTRACT

The albedo of seasonal snowpack exerts considerable control on the Earth's energy balance and is highly variable throughout space and time. Accurate quantification of snow albedo can be achieved through physically-based modeling approaches that are initialized or updated by optical satellite observations. Near-surface measurements are critical for validating both modeled and satellite-based reconstructions of snow albedo. Uncrewed Aerial Vehicles (UAVs) equipped with upward and downward-facing pyranometers provide high-resolution measurements of broadband albedo, spatially distributed across landscapes at scales not attainable by current satellite technologies. UAV surveys can deploy across heterogeneous terrain to acquire representative measurements of a diverse range of snow-covered environments, providing an improved source of calibration and validation data over traditional point-based measurements. Since UAV measurements can be taken near the surface (10 m - 100 m), they greatly reduce atmospheric and geolocational error sources. Near-surface measurements are still susceptible to other sources of error that must be corrected for if measurements are to be used operationally. Variable terrain introduces error in albedo measurements as reflectance measurements are not representative of surface conditions when they are taken at an oblique angle to the surface, introducing the need for topographically corrected albedo measurements. The tilt of the UAV platform can also compound this error.

We applied a novel tilt-topography correction to UAV-based, broad band snow albedo measurements to improve accuracy over sloped terrain. This correction is unique in that it utilizes spatially continuous raster surface models, and a cosine-weighted average of surface parameters (elevation, slope, and aspect), thus accounting for the large footprint and cosine response of pyranometers. Multiple UAV flights were performed in an alpine meadow in Southwest Montana (45.2316° N, 111.4768° W) using a DJI Matrice 210 v2 quadcopter equipped with upward and downward-facing Kipp and Zonen PR1 pyranometers. These sensors measure the integrated shortwave radiation from 310 – 2700 nm with a hemispherical field-of-view. Broadband albedo was calculated as the ratio between the downward and upward measurements. Individual albedo measurements were corrected for tilt using the UAV's inertial measurement unit (IMU), and topographically corrected using three different surface models. A high-resolution (0.1 m) snow-surface model was generated with Structure-from-Motion photogrammetry using overlapping imagery from a separate flight. A coregistered bare-surface model was also constructed using summertime UAV imagery. A 1/3 arc-second 3DEP (~10 m) DEM was used in a third correction. We compared the output of the tilt-topography corrections that utilized different elevation data sources to determine whether or not a snow-on surface model is required in order to produce accurate corrections. We also compared topographically corrected albedo data from flights at 10, 15, and 20 m altitude above ground-level to observe the effect of measurement scaling on comparisons to a Landsat 8-derived snow albedo product.

The mean/median values for topographically-corrected UAV measurements aligned well with the Landsat 8 values. The mean of corrected UAV-measured values was within 0.02 of Landsat 8 albedo regardless of elevation correction source. However, the range of values observed in the UAV measurements was larger than that present in the satellite data, indicating that the UAV-based platform detects higher spatial variability despite its large measurement footprint. When compared to Landsat 8 albedo, UAV albedo measurements showed decreasing RMSE and increasing bias with increasing flight altitude. Compared to Landsat 8 albedo, UAV measurements corrected with the snow-off photogrammetric model showed the highest RMSE and bias that is likely attributed to the variability introduced by vegetation that was not present in the snow-covered surface. The USGS 1/3 arc-second DEM showed the lowest RMSE and bias that is likely attributed to smoothing spatial variability due to lower surface model resolution. Overall, the differences in RMSE between elevation sources was less than 0.02. Bias had a maximum range of 0.04 between correction elevation sources.

Paper presented Western Snow Conference 2021
[1]Department of Earth Sciences, Montana State University, Bozeman, MT, USA
[2]Montana Institute on Ecosystems, Montana State University, Bozeman, MT, USA
[3]Electrical and Computer Engineering Department, Montana State University, Bozeman, MT, USA
[4]NASA Ames Research Center, Moffett Field, CA, USA

Based on these results we conclude that it is not necessary to perform a snow-on topographic survey contemporaneously with every snow-albedo UAV survey, since the elevation source does not critically impact the satellite comparison statistics. Since UAV surveys are limited by flight time and daylight hours, these findings promote larger albedo surveys as less time needs to be spent acquiring and processing topographic data. We observed that flight altitude has an impact on RMSE and bias. Therefore, in an operationalized UAV albedo validation campaign, flight altitude should be standardized between flights in different locations. It is important to note that this study was conducted in an alpine meadow environment, so findings may not be applicable to more variable landscapes. Future work will be focused on validating the proposed topography-tilt correction using ground-based measurements. (KEYWORDS: Topographic, albedo, uncrewed aerial vehicle, Landsat 8)