·Opinion Editorial· Advances in Polar Science
doi: 10.13679/j.advps.2017.4.00229 December 2017 Vol. 28 No. 4: 229-230

Optical remote sensing of snow fraction—status and future prospects

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Received 15 December 2017; accepted 30 December 2017

Keywords fractional snow cover, algorithm, NDSI

Citation: Appel I. Optical remote sensing of snow fraction—status and future prospects. Adv Polar Sci, 2017, 28 (4): 229-230, doi:10.13679/j.advps.2017.4.00229

Fractional snow cover (FSC) is that fraction of the surface covered with snow in a remotely sensed image pixel. This subpixel snow fraction is useful for atmospheric correction and to retrieve various satellite products characterizing the land surface, including albedo, temperature, soil moisture, heat fluxes, and vegetation parameters.

Most satellite-based snow cover products provide only a "binary" map, whereby each pixel is classified as either "snow" or "not snow". The FSC, in comparison, presents significant innovation and progress. The FSC was a product supplied from the Moderate Resolution Imaging Spectroradiometer (MODIS) onboard the Terra and Aqua satellites from launch until the end of 2016, and became a standard requirement for many users. However, from 1 January 2017 the program stopped providing the fractional snow product, although no other global products of snow fraction exist. This is a matter of significant concern creating problems for users of numerous applications.

A large scale international snow products intercomparison and validation project (htttp://snowpex.enveo.at) was initiated by the European Space Agency (ESA) and completed at the Environmental Earth Observation company in Innsbruck, Austria. This used almost 500 Landsat images to estimate the performance of different fractional snow algorithms. The high-resolution Landsat data provided reference snow fraction information (approximation of ground truth) for validation of moderate resolution satellite observations. The validation protocol agreed by the community includes classification and aggregation of 30-m pixels to estimate snow fraction within coarser cells to compare with matching moderate resolution FSC products. The validation results show that the snow fraction algorithm of Salomonson and Appel (2004) has advantages in comparison with other methods, both for open land and in forested areas for two reference data sets created using different techniques.

The Salomonson and Appel (2004) algorithm takes into account that the snow and non-snow reflective properties, even within a single satellite image, are very variable. However, snow and background endmembers could be characterized with a high accuracy by the Normalized Difference Snow Index (NDSI). This index, using visible and short wave infrared bands, was introduced (Hall et al., 1995) to map snow and distinguish snow from clouds. The enhanced NDSI-based algorithm explicitly accounts for changes in the endmembers from one image to another (Appel, 2014) using the equation

$$FSC = (NDSI - NDSI_{non\text{-}snow}) / (NDSI_{snow} - NDSI_{non\text{-}snow}),$$

where $NDSI_{snow}$ and $NDSI_{non\text{-}snow}$ are scene-specific snow and non-snow endmembers calculated in the algorithm on the fly.

The comparison of results provided by different techniques is a necessary stage in algorithm development.

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For example, the NDSI-based algorithm has been compared with the widely used tie-point algorithm—a simple version of a linear spectral mixture technique applied to a visible band. The performances of the two algorithms are estimated using the regressions of reference snow fraction on both visible reflectance and NDSI calculated from aggregating high-resolution observations to 5-km cells. The ordinary least squares method estimates the best fitting straight line minimizing the total distance between the regression line and the reference snow fraction points. In other words, the regressions on NDSI and reflectance represent the most accurate realizations of NDSI-based and tie-point algorithms characterized by the smallest possible root mean square errors for each individual image. This comparison of the algorithms demonstrates advantages of the NDSI-based approach: smaller correlation coefficient (0.85 vs 0.95) and 60% increase in the standard deviation (more than 100% in variance) for the regressions on visible reflectance (Figure 1) in comparison with the regressions on NDSI for 16 scenes described by Appel (2014).

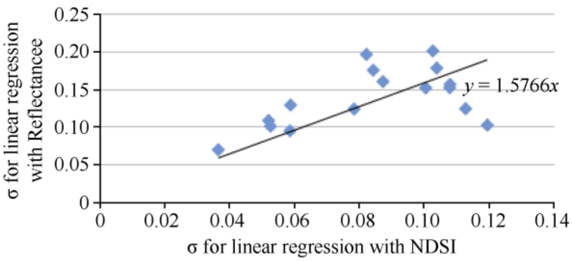

Figure 1 Standard deviation for snow fraction regression on visible reflectance vs standard deviation for regression on NDSI.

Estimation of fractional snow cover is not a low priority task due to user requirements, and because this property of the snow that covers up to 40% of land in the Northern Hemisphere is critical for retrieval of many atmosphere and land products.

A key factor explaining why no center currently provides a global fractional snow product is the problem of snow misidentification in regions where it never exists. Attempts to eliminate such errors using different kinds of masking are not always effective.

An alternative, more promising approach to decrease false snow retrieval, is dynamic adjustment of the FSC algorithm parameters to specific conditions of observations and surface state. The optimal way to derive moderate resolution optical remote sensing information on fractional snow cover should allow for the local variability of snow and non-snow reflective properties within a scene-specific algorithm. Creation of unbiased and consistent information on fractional snow cover is required for global studies as well as for numerous regional and local scale applications.

The significance of the fractional snow product has been confirmed by the decisions made by ESA and the Japan Aerospace Exploration Agency (JAXA) to estimate snow fraction using optical observations from Sentinel-3 and the Global Change Observation Mission—Climate (GCOM-C) respectively.

However, the approaches used to retrieve snow fraction, proposed for Sentinel-3 and GCOM-C missions are noticeably different from that for MODIS. The intercomparison of the results provided by different fractional snow retrieval algorithms needs to be considered as an essential stage in their assessment and thorough validation is required at the earliest possible stages of algorithm development.

Collaboration between researchers with experiences supplementing each other can be a very promising way to tackle the problem of optimizing fractional snow algorithm development. Such collaboration should be considered as a key recommendation for developing snow product algorithms and other related activities.

References

Appel I. 2014. Retrieval and validation of VIIRS snow cover information for terrestrial water cycle applications//Remote Sensing of the Terrestrial Water Cycle, edited by Venkataraman Lakshmi, AGU, Washington, D. C.: Wiley, 175-198, doi: 10.1002/9781118872086

Hall D K, Riggs G A. Salomonson V V. 1995. Development of methods for mapping global snow cover using moderate resolution imaging spectroradiometer data. Remote Sensing of Environment, 54(2), 127-140, doi: 10.1016/0034-4257(95)00137-P

Salomonson V V and Appel I. 2004. Estimating fractional snow cover from MODIS using the normalized difference snow index. Remote Sensing of Environment, 89(3): 351-360, doi:10.16/j.rse.2003.10.016

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