Session: YSPS.2.1
Poster number: 192

DRAGON 2021 SYMPOSIUM 19 July 2019 | Online

GLACIER ENERGY BALANCE ESTIMATION BY CONSIDERING REFLECTANCE ANISOTROPY OF THE GLACIER SURFACE FOR ALBEDO RETRIEVAL

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ABSTRACT

Glacier albedo directly determines net shortwave radiation, thus affects glacier energy balance. Complex terrain leads to anisotropy reflectance on glacier surface, however, limited anisotropy correction model is a major limitation of current glacier albedo retrieval and energy balance estimation. In this study, we improved glacier albedo retrieval for Landsat 8/Operational Land Imager (L8/OLI) and Moderate Resolution Imaging Spectroradiometer (MODIS) using calibrated anisotropy correction models for glacier snow and ice. The results show that the albedos retrieved by our method have a better absolute accuracy and time evolution. Since our anisotropy correction models cover the primary satellite shortwave bands for earth observation, this method is promising to improve albedo retrieval with Sentinel-2/MultiSpectral Instrument (S2/MSI) data and other satellite data.

OBJECTIVES

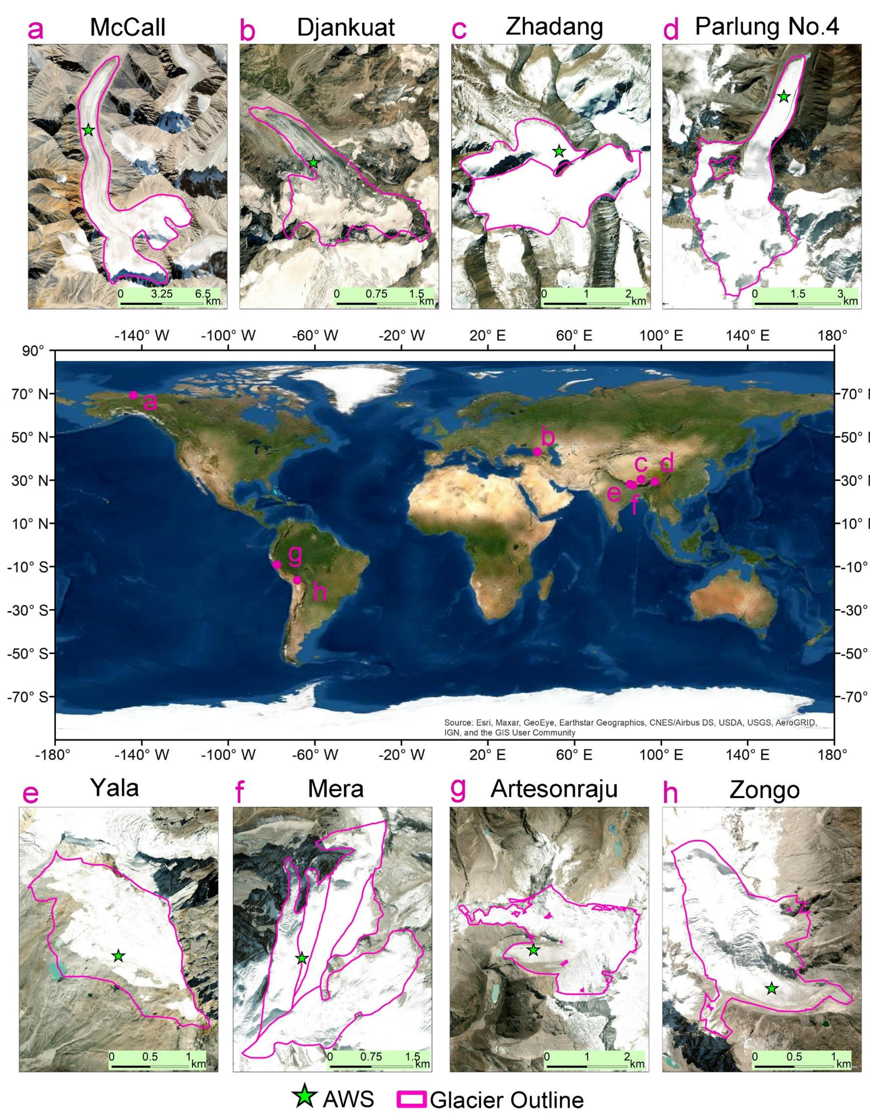

Figure.1 Location of eight glaciers with their AWSs

The main objective of this study is to improve glacier albedo retrievals by considering anisotropy reflectance on glacier surface. Based on available data, we compiled eight on-glacier Automatic Weather Stations (AWSs) records to calibrate and evaluate the albedo retrieval method (Fig. 1). These glaciers are located in diverse mountain ranges around the world encompassing different climates from low (<2000 m a.s.l) to high elevation (>5000 m a.s.l). The AWSs were situated on different glacier surfaces of snow, ice or a mixture of ice and debris, so different surface types were accounted for in our satellite albedo retrieval validation.

METHODS

Albedo retrieval from remote sensing data generally requires three steps: atmospheric correction, anisotropy correction and Narrowband-To-Broadband (NTB) conversion. In this study, we developed a new broadband albedo retrieval method by combining our anisotropy correction model and Liang (2001) NTB, hereafter referred to as This Study. Finally, we compared our results with previous method (hereafter referred to as Knap) for L8/OLI (Wang et al., 2014) and for an official MODIS albedo product (MCD43A3), respectively.

RESULTS

L8/OLI albedo VS AWS albedo. The albedos retrieved by the method in this study have small Mean Absolute Error (MAE) and Root Mean Squared Error (RMSE), indicating better accuracy than the Knap method for L8 data (Fig. 2)

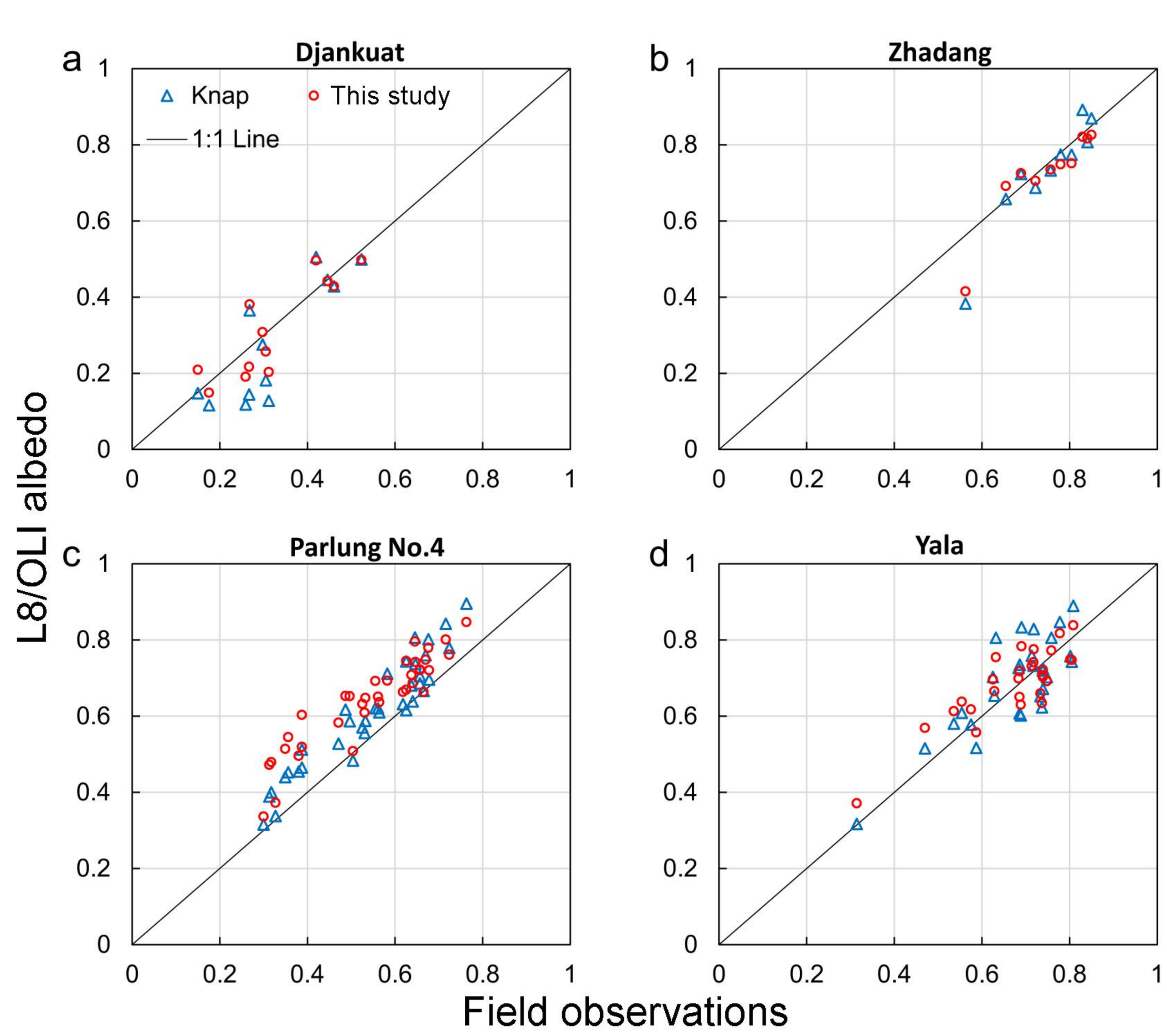

Figure. 2 Broadband albedo from AWSs versus broadband albedo from overlapping L8/OLI pixels with the Knap and this study methods for four of the study glaciers for which observations overlapped with L8/OLI images.

MODIS albedo VS L8/OLI albedo. Compared with MCD43A3 product, there are three advantages for the albedos retrieved by the method in this study: 1) it has a higher absolute accuracy despite MODIS albedos being overestimated (Fig. 3); 2) it can retrieve more available albedos because our method can successfully retrieve for any clear-sky day, while MCD43A3 needs enough observations during a 16-day window (Figs. 4); 3) it has a better time evolution and can better capture albedo large fluctuations caused by snowfall (Fig. 5).

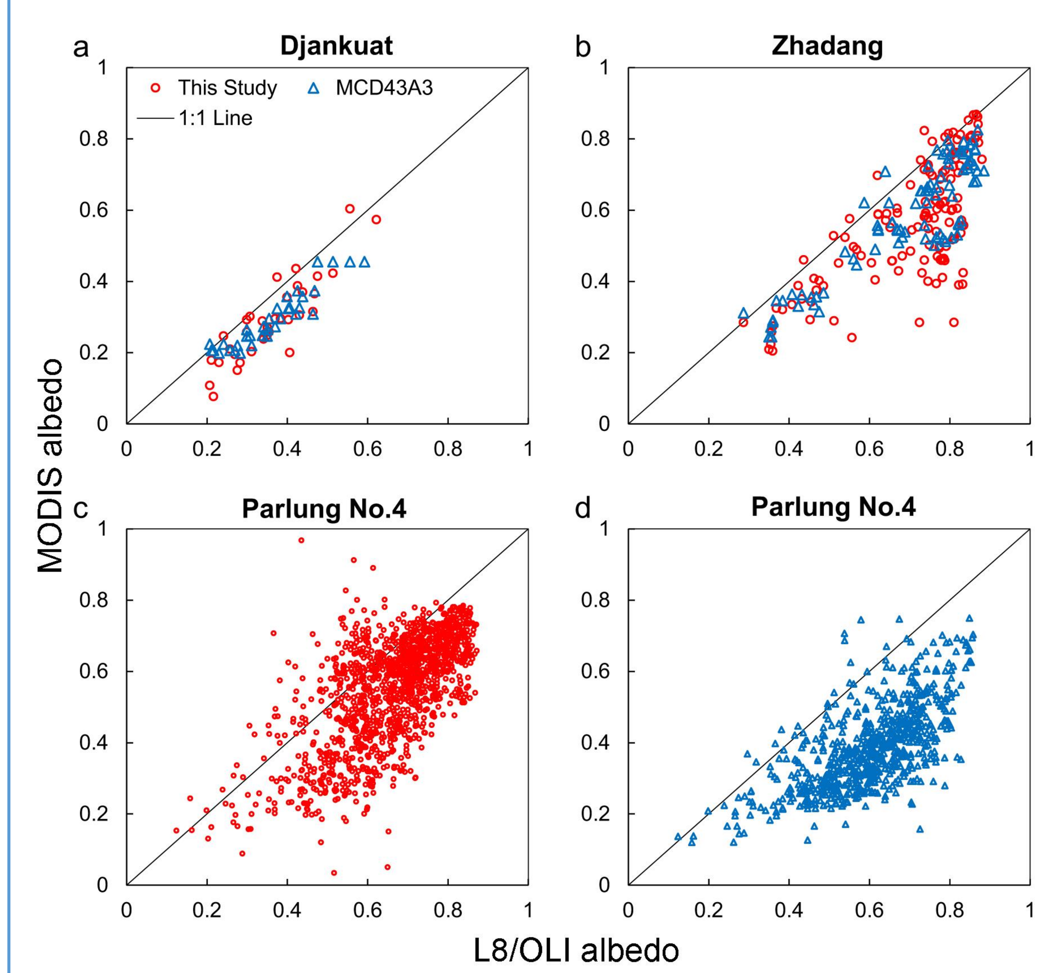

Figure 3. Same as Fig. 2, but for MODIS albedo versus L8/OLI albedo

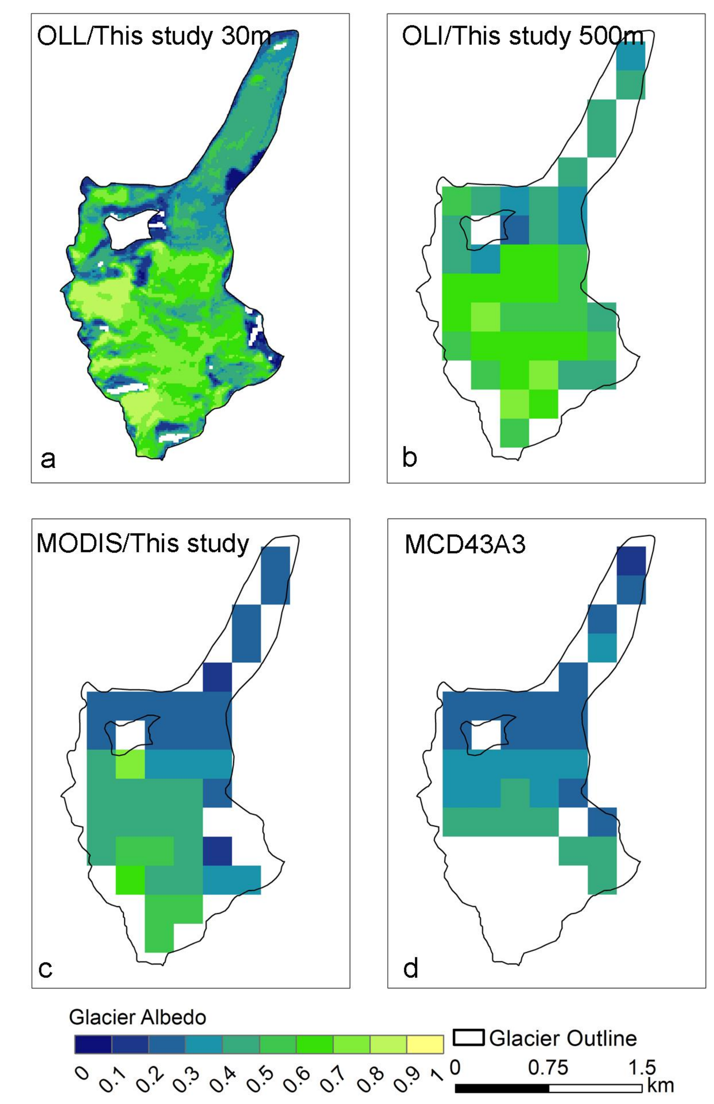

Figure 4. Comparison of albedo among (a) 30 m OLI/This study, (b) 500 m OLI/This study, (c) MODIS/This study and (d) MCD43A3 albedo products over the Parlung No.4 Glacier on 6 December 2014.

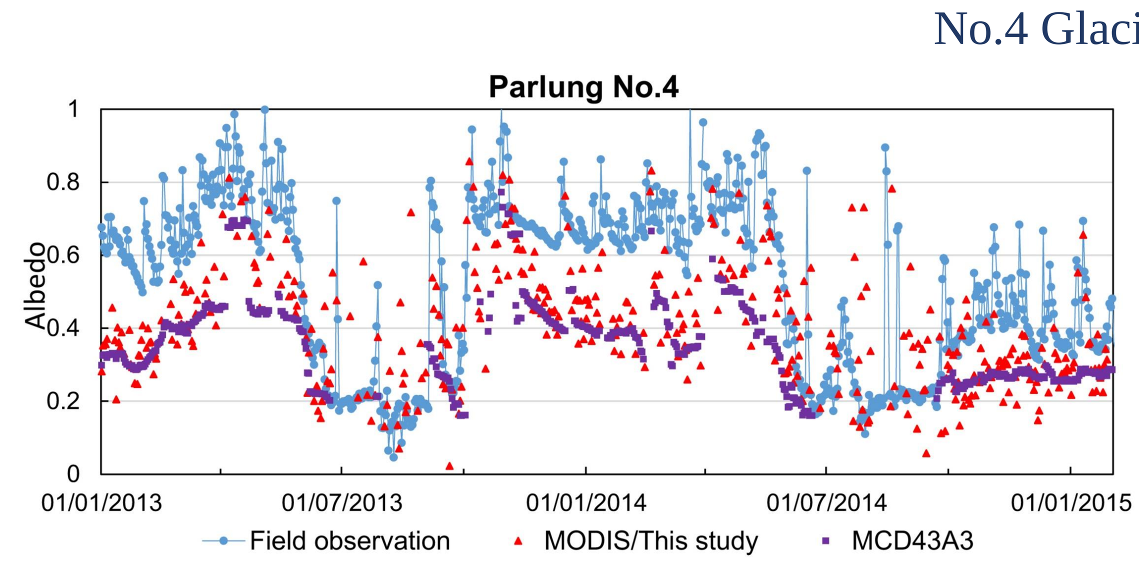

Figure 5. MODIS/This study, the MCD43A3 albedo products and field observations for Parlung No.4 Glacier

CONCLUSIONS

In this study, we developed anisotropy correction models applicable to glacier snow and ice surface reflectance with high-quality airborne BRDF measurements and developed new albedo retrieval methods for L8/OLI and MODIS by combing the best performing model and Liang (2001) narrowband to broadband conversions. The results show that the new method can retrieve better albedo with these two data and improve glacier energy balance estimation. Our method is also promising for S2/MSI and other satellite data.

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ACKNOWLEDGEMENT

This research was funded by the Second Tibetan Plateau Scientific Expedition and Research Program (STEP) (grant no. 2019QZKK0103); the National Natural Science Foundation of China project (grant no. 91737205) and the European Research Council (ERC) under the European Union's Horizon 2020 research and innovation programme (grant no. 772751).

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