THE VALIDATION OF SNOW COVER PRODUCT OVER HIGH MOUNTAIN ASIA

Xu Su, Lingmei Jiang, Gongxue Wang, Jian Wang*

State Key Laboratory of Remote Sensing Science, Jointly Sponsored by Beijing Normal University and Aerospace Information Research Institute of Chinese Academy of Sciences, Faculty of Geographical Science, Beijing Normal University, Beijing 100875, China
* Corresponding author. E-mail address: jiang@bnu.edu.cn.

ABSTRACT

Many algorithms and products for snow cover have been developed. Then a unified set of "ground truth" data is important to validate snow cover products. In this study, Landsat-8/OLI data processed by linear unmixing algorithm was determined as "ground truth" to validate the moderate resolution snow products. In order to evaluate the cloud removing effect of the daily fractional snow cover (FSC) dataset of MODIS over High Asia, we use the MOD10A1 FSC product which is calculated by recommended equations as the before cloud removing data, then the Landsat-8/OLI FSC was used to validate both of the MODIS data. The results show that when the percentage of cloud pixels is less than 10%, the binary accuracy can reach 0.85 or more, the mean absolute error is less than 0.25, and the root mean square error is less than 0.35. These results suggest that the product has high credibility, despite there is still a small amount of cloud in the product.

Index Terms—Fractional snow cover, Landsat-8/OLI, MODIS, Validate

1. INTRODUCTION

Changes in snow cover have important implications for water and energy balance and the study of snow cover on the High Asia is very important for global climate change. At present, researchers have developed lots of algorithms to calculate snow cover[1-8], using the algorithms they have produced a lot of binary and fractional snow cover products[9-13]. Different snow products have different precision and we do not know whether the existing products can meet the demand of model. We need to validate them and find the most fit product to operate over the study area.

There are many mixed pixels, in order to obtain more accurate retrieval results, the researchers have developed the linear spectral mixture analysis method[3, 4]. Landsat-8/OLI is available for free and has high spatial resolution, therefore, we used linear unmixing algorithm to calculate Landsat-8/OLI FSC and then get the 'ground truth' data. Then we use the "ground truth" data validates the fractional snow cover products so that we can assess these products in the same way. In this paper, we choose the daily fractional snow cover dataset over High Asia [10] to evaluate the precision and cloud removing effect.

2. STUDY REGION AND DATA

2.1. Study region

The study area is located in the High Mountain Asia, which is the high-altitude area centered on the Tibet Plateau, located in central Asia, with latitude and longitude of about 26°N-46°N and 62°E-105°E.

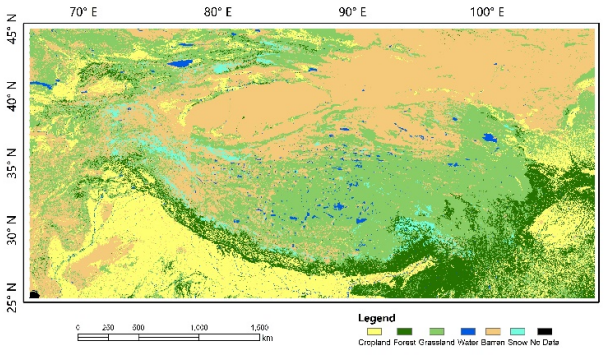

Figure.1. Study area over the High Mountain Asia

2.2. Data

2.2.1. Daily fractional snow cover dataset over High Asia

Daily fractional snow cover dataset over High Asia (HMA_MODIS FSC) is produced by Qiu and et al[10]. The data has the spatial resolution of 500 meters and is derived from the MODIS normalized snow index (NDSI) data. A variety of cloud elimination algorithms were used in data processing. The dataset has the cloud cover less than 10%, and it can meet the input requirements of hydrological and energy models.

2.2.2. MOD10A1

MOD10A1 (Terra) is obtained from the National Snow & Ice Data Center (NSIDC) and is in the MODIS snow cover product collection 6, as the fractional snow cover is no longer calculated in this version, we use the empirical relationship which is first developed by Salomonson and Appel[14] to get the MOD10A1 FSC. The relationship can be expressed as:

$$f_{SCA} = -0.01 + 1.45 * NDSI$$

$$NDSI = \frac{B_4 - B_6}{B_4 + B_6}$$

Where the B_4 is Band 4 (0.545-0.565 μm, red band) and B_6 is Band 6 (1.628-1.625 μm, shortwave infrared band) in MODIS data, respectively.

2.2.3. Landsat-8/OLI FSC— 'Ground truth'

The Landsat-8/OLI FSC data used in this study was derived from Landsat-8/OLI surface reflectance data with the linear unmixing algorithm. In order to know whether this Landsat-8/OLI FSC can meet the requirements as the "ground truth" data, we use the GF-2 data which has higher resolution to evaluate. The conclusion is that Landsat-8/OLI FSC calculated with the linear unmixing algorithm can be used as "ground truth"[15].

3. METHODS

Compared with MOD10A1 FSC, HMA_MODIS FSC has eliminated cloud. We use Landsat-8/OLI FSC to validate MOD10A1 FSC and HMA_MODIS FSC, respectively. Then we can know the post-processing effect of this product. We selected satellite images dates when they meet both of the following two conditions: 1) the MOD10A1 images were cloudy; 2) the Landsat-8/OLI images have less cloud cover. In this paper, we mainly display the validation results of the 6 satellite images, because the 6 images corresponding to the Landsat-8/OLI images are of good quality. We use the snow cover evaluation indicators and the binary evaluation indicators, such as R-squared, MAE, RMSE, Precision and Accuracy to evaluate the validation results.

4. RESULTS

More than thirty Landsat-8/OLI images of different landcover types were used to validate this dataset. The result shows that the dataset has a good post-processing effect. Figure.2. shows the scene 141034 on 12 December 2016 of Landsat-8/OLI. The landcover type of this image is grassland, water and barren. Figure.3. shows the fractional snow cover of Landsat-8/OLI, MOD10A1, and HMA_MODIS. Compared to Landsat-8/OLI, both MOD10A1 and HMA_MODIS has underestimate snow cover, while Landsat-8/OLI with linear unmixing algorithm showed more details on the snow. Figure.4. shows the fractional snow cover comparison of Landsat-8/OLI and HMA_MODIS at different spatial resolution. With the scale increasing, the correlation between the two becomes better. We list some validation results in Table 1. Including Landsat-8/OLI respectively validate the data before removing cloud and after removing cloud. To further explore the effects of post-processing, we counted the number of pixels participating in each validation and get the corresponding evaluation index value.

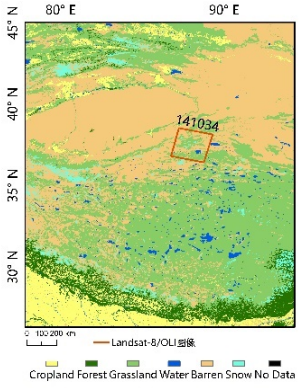

Figure.2. Scene 141034 on 12 December 2016

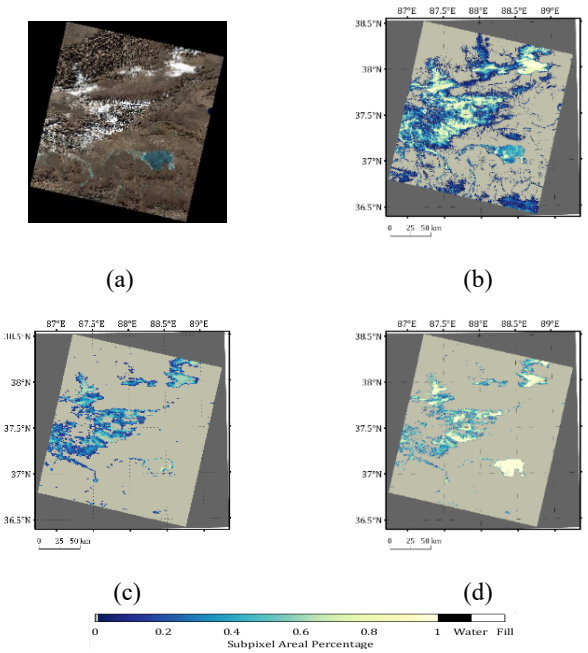

Figure.3. Fractional snow cover comparison of Landsat-8/OLI, MOD10A1 and HMA_MODIS: (a) Landsat-8/OLI false-color, (b) fractional snow cover from Landsat-8/OLI, (c) fractional snow cover from MOD10A1 and (d) fractional snow cover from HMA_MODIS.

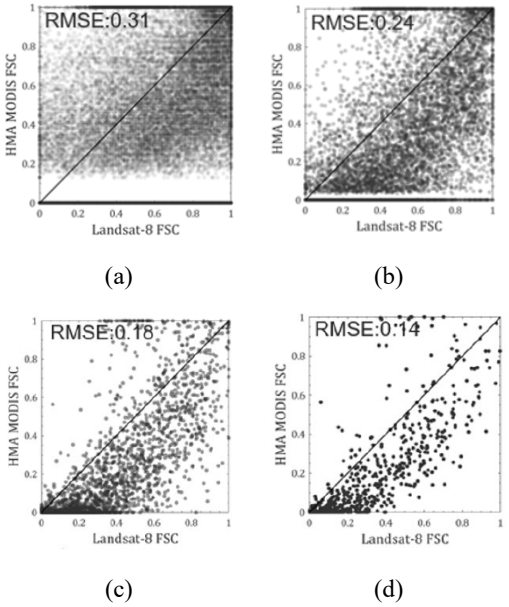

Figure.4. Fractional snow cover scatter of Landsat-8/OLI and HMA_MODIS at different spatial resolution scales: (a) 500 m, (b) 1 km, (c) 2.5 km and (d) 5 km.

Table 1. The validation results for Landsat-8/OLI and MODIS

Date	Percentage of Cloud pixels (Before)	N1	Percentage of Cloud pixels (After)	N2	Window	Lst-8 vs images(Before)			Lst-8 vs images(After)		
						B Precision	MAE	RMSE	B Precision	MAE	RMSE
2016.08.28	14.4%	210787	2.7%	231542	1*1	0.86	0.24	0.34	0.88	0.24	0.33
					2*2	0.87	0.16	0.25	0.89	0.16	0.24
					5*5	0.87	0.10	0.17	0.89	0.09	0.14
					10*10	0.87	0.07	0.13	0.89	0.07	0.10
2016.11.11	7.3%	194703	3.7%	213149	1*1	0.77	0.33	0.43	0.87	0.20	0.29
					2*2	0.76	0.26	0.36	0.89	0.14	0.22
					5*5	0.73	0.19	0.28	0.90	0.10	0.16
					10*10	0.71	0.16	0.24	0.91	0.07	0.12
2016.12.04	19.9%	171262	2.4%	201557	1*1	0.79	0.25	0.37	0.87	0.17	0.26
					2*2	0.80	0.20	0.31	0.89	0.11	0.18
					5*5	0.44	0.15	0.26	0.91	0.07	0.12
					10*10	0.79	0.13	0.23	0.92	0.05	0.09
2016.12.12	4.0%	217824	0.5%	218265	1*1	0.87	0.24	0.34	0.87	0.22	0.31
					2*2	0.87	0.19	0.28	0.88	0.16	0.24
					5*5	0.86	0.13	0.22	0.88	0.11	0.18
					10*10	0.86	0.11	0.18	0.89	0.09	0.14
2016.12.18	5.1%	200316	0.1%	203492	1*1	0.89	0.17	0.24	0.91	0.19	0.27
					2*2	0.91	0.11	0.17	0.93	0.12	0.18
					5*5	0.93	0.06	0.11	0.95	0.07	0.12
					10*10	0.93	0.04	0.08	0.95	0.05	0.09
2016.12.20	25.3%	166602	7.5%	199432	1*1	0.70	0.39	0.50	0.84	0.29	0.41
					2*2	0.75	0.32	0.44	0.87	0.23	0.33
					5*5	0.80	0.24	0.36	0.91	0.17	0.25
					10*10	0.82	0.20	0.32	0.92	0.14	0.20

In Table 1, the data before cloud removal refers to MOD10A1, and the data after cloud removal refers to data from Daily fractional snow cover dataset over High Asia. The 1 * 1, 2 * 2, 3 * 3, and 10 * 10 represent 500 m, 1 km, 2.5 km, and 5 km spatial resolutions, respectively.

5. CONCLUSION AND DISCUSSION

Using the "ground truth" data to validate the snow cover product over High Asia, the results show that when the percentage of cloud pixels is less than 10%, the binary accuracy can reach 0.85 or more, the mean absolute error is less than 0.25, and the root mean square error is less than 0.35, the dataset have better precision. Comparing the results of the fractional snow cover product validation before and after removing the cloud, the value of the evaluation statistics after removing cloud and before removing cloud is basically the same, and the product has better cloud removing effect. Comparing the validation results of different scales, it can be found that with the increase of the scale, the binary precision, the mean absolute error and the root mean square error are basically improved in accuracy and reduced in error. These results suggest that the product has high credibility and can help researchers do research on hydrological and energy balance over High Asia.

6. ACKNOWLEDGEMENTS

This study is jointly supported by the Second Tibetan Plateau Scientific Expedition and Research Program

(STEP) (2019QZKK0206), and the National Natural Science Foundation of China (41671334).

7. REFERENCES

[1] D. K. Hall, G. A. Riggs, and V. V. Salomonson, "Development of methods for mapping global snow cover using moderate resolution imaging spectroradiometer data," *Remote Sensing of Environment,* vol. 54, no. 2, pp. 127-140, Nov.1995.

[2] J. Dozier, "Spectral signature of alpine snow cover from the landsat thematic mapper," *Remote Sensing of Environment,* vol. 28, pp. 9-22, Apr.1989.

[3] T. H. Painter, D. A. Roberts, R. O. Green, and J. Dozier, "The Effect of Grain Size on Spectral Mixture Analysis of Snow-Covered Area from AVIRIS Data," *Remote Sensing of Environment,* vol. 65, no. 3, pp. 320-332, Sept.1998.

[4] J. Shi, "An Automatic Algorithm on Estimating Sub-Pixel Snow Cover from MODIS," *Quaternary Sciences,* vol. 32, no. 1, pp. 6-15, Jan.2012.

[5] A. G. Klein, D. K. Hall, and G. A. Riggs, "Improving snow cover mapping in forests through the use of a canopy reflectance model," *Hydrological Processes,* vol. 12, no. 10-11, pp. 1723-1744, Aug.1998.

[6] S. Singh, V. Sood, R. Kaur, and S. Prashar, "An efficient algorithm for detection of seasonal snow cover variations over undulating North Indian Himalayas, India," *Advances in Space Research,* vol. 64, no. 2, pp. 314-327, Jul.2019.

[7] W. Rosenthal and J. Dozier, "Automated Mapping of Montane Snow Cover at Subpixel Resolution from the Landsat Thematic Mapper," *Water Resources Research,* vol. 32, no. 1, pp. 115-130, Jan.1996.

[8] N. Foppa, S. Wunderle, and A. Hauser, "Spectral unmixing of NOAA-AVHRR data for snow cover estimation," 2002.

[9] T. H. Painter, K. Rittger, C. McKenzie, P. Slaughter, R. E. Davis, and J. Dozier, "Retrieval of subpixel snow covered area, grain size, and albedo from MODIS," *Remote Sensing of Environment,* vol. 113, no. 4, pp. 868-879, Apr.2009.

[10] Y. Qiu, X. Wang, L. Han, L. Chang, and L. Shi, "Daily fractional snow cover dataset over High Asia," Science Data Bank, (2018-10-29). DOI: 10.11922/sciencedb.457.

[11] P. Bicheron, C. Henry, S. Bontemps, and G. Partners, "Globcover Products Description Manual," *MEDIAS-France: Toulouse, France,* 2008.

[12] D. K. Hall, G. A. Riggs, V. V. Salomonson, N. E. DiGirolamo, and K. J. Bayr, "MODIS snow-cover products," *Remote Sensing of Environment,* vol. 83, no. 1, pp. 181-194, Nov.2002.

[13] Z. Tang, J. Wang, L. Yan, H. Li, and J. Liang, "Estimating sub-pixel snow cover from MODIS in Qinghai-Tibet Plateau," *Journal of Arid Land Resources and Environment,* vol. 27, no. 11, pp. 33-38, Nov.2013.

[14] V. V. Salomonson and I. Appel, "Estimating fractional snow cover from MODIS using the normalized difference snow index," *Remote Sensing of Environment,* vol. 89, no. 3, pp. 351-360, Feb.2004.

[15] S. Hao, L. Jiang, J. Shi, G. Wang, and X. Liu, "Assessment of MODIS-Based Fractional Snow Cover Products Over the Tibetan Plateau," *IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing,* vol. 12, no. 2, pp. 533-548, Feb.2019.