ACCURACY EVALUATION OF SEVERAL AVHRR FRACTIONAL SNOW COVER RETRIEVAL ALGORITHMS IN ASIA WATER TOWER REGION

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ABSTRACT

Advanced Very High Resolution Radiometer(AVHRR) has accumulated nearly 40 years of data, making it essential for long time series snow monitoring. However, the majority of AVHRR snow algorithms and products are binary forms, which can have a significant impact on hydrological process simulations and estimates of water and energy cycles. Based on AVHRR data, three fractional snow cover retrieval algorithms are implemented in this study: the multiple endmember spectral mixture analysis algorithm based on automatic endmember extraction (MEAMA-AGE), the Snow Index method and the Snow/no-Snow Two-endmember model algorithm. In order to compare and verify the accuracy of the three fractional snow cover retrieval algorithms, we use the high spatial resolution Landsat-8 image snow cover retrieval results as the "ground truth". The results show that all three algorithms can effectively retrieve fractional snow cover from AVHRR data, among which the Snow Index method and the Two-endmember model algorithm have higher accuracy, while the MESMA-AGE algorithm has lower precision due to the influence of the endmembers representation.

Index Terms— AVHRR, Landsat-8, Fractional snow cover, MESMA-AGE, NDSI, Two-Endmember Model

1. INTRODUCTION

The Asian Water Tower region, with the Tibetan plateau at its core, has the largest amount of snow outside the poles and is becoming unbalanced as the climate warms, which is seriously affecting global climate change and the water cycle. In the meantime, as one of the most active elements in the cryosphere, snow cover is an important input parameter in the study of global climate change, surface radiation energy and water cycle. AVHRR is a sensor in NOAA's weather satellite series, which has accumulated data for nearly 40 years, making it some of the key data of large-scale and long-time series land surface parameter retrieval, especially for snow cover.

There are two types of snow remote sensing research based on AVHRR image: one is binary snow mapping, the other is fractional snow cover retrieval. Binarization snow cover mapping is mainly carried out by using decision tree algorithm. These algorithms use a series of rules such as single-band reflectance value, NDSI and NDVI to identify snow cover. And has released global or local snow binary products. For example, Japan's JAXA snow pack binary product-JASMES[1], which is a 5km daily snow product in the Northern Hemisphere. The Northwest Academy of the Chinese Academy of Sciences has also released a set of 5km day-to-day cloud-free snow binary product[2]. For the thin and fragmented snow cover of the Qinghai-Tibet Plateau, the binary snow information obtained from the medium and low spatial resolution images brings much uncertainty and deviation for the accurate estimation of the snow distribution in the region.

There are few studies on snow cover retrieval based on AVHRR data, for example, Slater used AVHRR image data to retrieval fractional snow cover based on the difference of NDVI values between snow cover and non-snow cover in winter[3]. The GlobSnow fractional snow cover product released by ESA using SCAmod method has high precision in forest areas[4], but its precision in China is limited due to the dependence of SCAmod input parameters on training samples.

In this paper, we use MESMA-AGE algorithm, Snow Index method and the Snow/no-*S*now Two-endmember model algorithm developed by our team to perform fractional snow cover retrieval over the Asia Water Tower. Finally, we use high spatial resolution Landsat-8 image data as the 'ground truth', the accuracy of three snow cover retrieval algorithms is evaluated.

2. STUDY AREA AND DATA

2.1. Study Area

The snow cover in the Asian Water Tower region, with the Tibetan Plateau as the core, affects the water cycle and energy exchange in China and even in the high Asian region. Therefore, a set of fractional snow cover products with long

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time series and high precision spatial-temporal continuity is urgently needed to meet the demand of monitoring snow cover characteristics on the Asian Water Tower region. In this paper, the accuracy of three snow cover retrieval algorithms is analyzed comprehensively to get the applicability of each algorithm in Asian Water Tower region, and to pave the way for the subsequent production of related products.

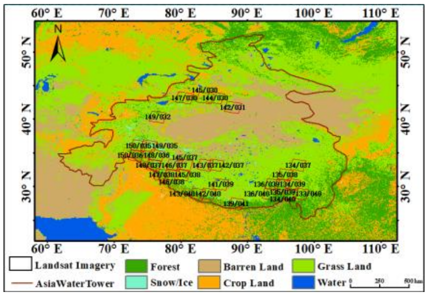

Figure.1 Study area and Landsat image location

2.2. Data

AVHRR is a sensor carried on board the NOAA series of meteorological satellites, which has been conducting continuous Earth observation missions since the launch of the TIROS-N satellite in 1979. The Data used in this study is AVH09C1 surface reflectance value product, produced by NASA's Long Term Data Record team. The latest version of AVH09C1 is V5, which is fully after atmospherically corrected, satellite drift corrected, sensor radiation corrected. The product has a spatial resolution of 5km and a temporal resolution of daily. The following table 1 shows the band setting of AVHRR.

Table 1 AVHRR/3 band settings

Channel	*Band*	*Wavelength (μm)*
1	Visible	0.58-0.68
2	Near-infrared	0.73-1.00
3A	Short-wave infrared	1.58-1.64
3B	Mid-infrared	3.55-3.93
4	Thermal infrared	10.30-11.30
5	Thermal infrared	11.50-12.50

3. METHODOLOGY/N

3.1. MESMA-AGE Algorithm(MESMA)

In this paper, we first use the MESMA-AGE algorithm for fractional snow cover retrieval[5], which has been verified by Hao[6] to be optimal in the Tibetan Plateau region. Its algorithmic principle is as follows:

$$R_\lambda = \sum_{i=1}^{n} F_i R_{i,\lambda} + \varepsilon_\lambda \qquad (1)$$

where F_i is what is to be solved, the areal fraction of endmember i with reflectance $R_{i,\lambda}$ at wavelength λ; $R_\lambda$is the mixed pixel's reflectance and ε_λ is residual error.

In this study, we used NDSI, NDVI and visible band reflectance value data to combine a series of rules for automatic extraction of snow cover and non-snow(Vegetation, bare ground, Shadows) endmember, the typical endmember library is used to retrieve fractional snow cover using MESMA algorithm.

3.2. Snow Index Algorithm(SI)

The algorithm was first used in MODIS snow cover retrieval. Salomonson[7] found that there was a good linear relationship between the fractional snow cover of Landsat-7/ETM + and the NDSI values of Terra and Aqua MODIS. Based on this relationship, a snow cover estimation method based on the snow index NDSI is established. NASA/MODIS officials used this fitting relationship as the fifth version of the snow product retrieval algorithm. The principle is as follows:

$$FSC = \frac{NDSI - NDSI_{no-Snow}}{NDSI_{Snow} + NDSI_{no-Snow}} \qquad (2)$$

$NDSI_{no\text{-}Snow}$ is the NDSI value of non-snow background, $NDSI_{Snow}$ is the NDSI value of snow background, $NDSI$ is the NDSI value of the pixel to be solved. In order to simplify the extraction of background NDSI, a certain number of samples were selected for aggregation analysis, and the corresponding background NDSI values were obtained.

3.3. Snow/no-Snow Two-endmember model Method(TM)

If we assume that the proportion of snow cover ratio (fractional snow cover) in the mixed pixel is proportional to the proportion of pure snow signal to the total signal, fractional snow cover can then be estimated by linear interpolation between snow-free and pure snow signals. The snow index method described above actually uses the NDSI signal. In this study, snow cover was obtained by linear interpolation based on the reflectance value of snow-covered and snow-free surfaces. This method needs to consider the variation of snow reference reflectance value with snow properties, seasons and surface types[8].

$$FSC = \frac{VIS - VIS_{no-Snow}}{VIS_{Snow} + VIS_{no-Snow}} \qquad (3)$$

$VIS_{no\text{-}snow}$ is determined by the mode of the reflectivity value of the pure snow endmember of the surface type. VIS_{snow} is determined by the mode of the reflectance value of the snow-free endmember, VIS is the reflectance value of the pixel to be solved.

4. RESULTS

The cloud identification of AVH09C1 V5 products is seriously misidentified[1][2], so the cloud identification of AVH09C1 V5 products is carried out according to the cloud identification algorithms of JAXA[1] and Northwest

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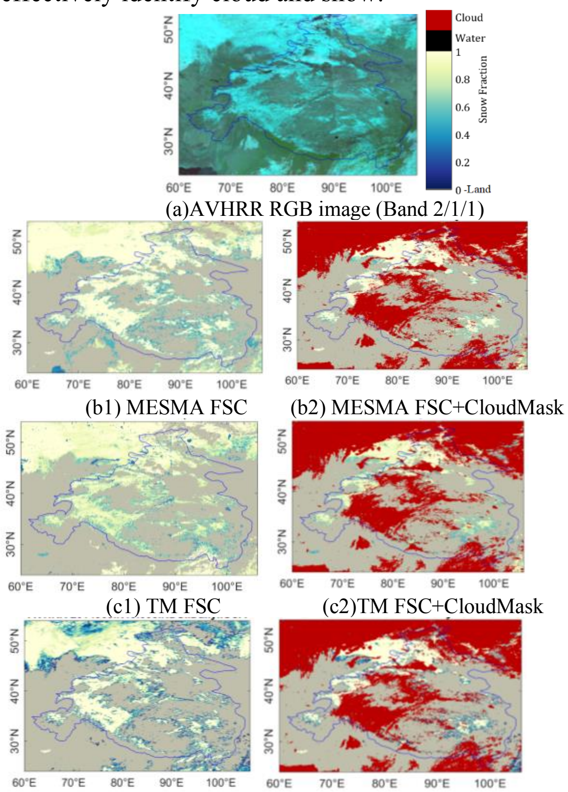
Academy of Chinese Academy of Sciences[2]. Compared with Figure 2(a) and Figure 2(b1)(c1)(d1) , we can see these three algorithms are all effective in fractional snow cover retrieval. As can be seen from Figure 2(a) and Figure 2(b2)(c2)(d2) , the new cloud identification algorithm can effectively identify cloud and snow.



(a)AVHRR RGB image (Band 2/1/1)

(b1) MESMA FSC (b2) MESMA FSC+CloudMask

(c1) TM FSC (c2)TM FSC+CloudMask

(d1)SI FSC (d2) SI FSC+CloudMask

Figure.2 Comparison of results of different fractional snow cover retrieval algorithm(2014.12.31)

It can be seen from Fig. 2 (b1) (c1) (d1) that there are some differences in the fractional snow cover results retrieved by the three algorithms. For example, Figure 2(b1) and Figure 2(d1) are the retrieval results of MESMA algorithm and SI algorithm respectively. It can be seen from the results that they have good consistency. Although they can effectively identify the snow cover, they lose a lot of spatial details. As shown in Figure 2 (c1), the result value of TM algorithm is generally low, but it contains more spatial details. This is because all kinds of endmembers of this algorithm are further subdivided according to the surface type, so the representation of all kinds of endmembers is better.

In order to further evaluate the accuracy of three fractional snow cover retrieval algorithms, we evaluated four land surface types, namely bare land, grassland, forest and plateau mountainous area, using landsat8 image data. Because there are many high mountains in the Asian water tower area and the accuracy of the existing algorithms is often low the mountainous area, this study selects more the plateau mountainous area as the surface type when verifying the regional selection. The location of the Landsat 8 image for validation is shown in the red box in Figure 1. In order to better illustrate the accuracy of each algorithm, we selected two scene images (more and less snow cover each scene) to show the verification results. The accuracy evaluation results are shown in Table 1 below.

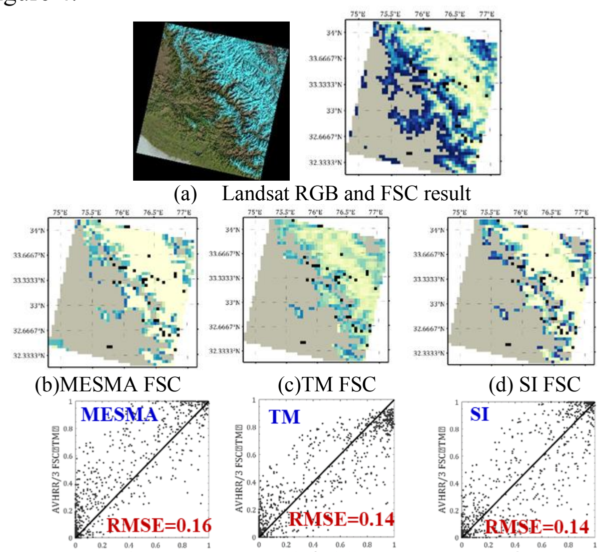
MESMA/TM/SI Accuracy verification results

Landcover	Path/Row	Date	Accuracy	RMSE
Bare land	142031	20150131	0.91/0.90/0.88	0.18/0.16/0.17
	145030	20140306	0.97/0.96/0.95	0.19/0.16/0.19
Grass land	143037	20140119	0.96/0.97/0.97	0.20/0.14/0.15
	145037	20140218	0.97/0.97/0.96	0.24/0.17/0.19
Forest	148037	20150109	0.89/0.90/0.90	0.16/0.14/0.14
	133040	20150321	0.79/0.81/0.83	0.25/0.23/0.22
Plateau mountain	150035	20150312	0.92/0.94/0.93	0.20/0.18/0.19
	146038	20140209	0.97/0.97/0.97	0.20/0.15/0.17
	149035	20140129	0.96/0.96/0.96	0.17/0.16/0.17

Table 1 MESMA/TM/SI Accuracy verification results

It can be seen from the result in Table 1 that the three algorithms have good accuracy. The accuracy of the three algorithms is higher in bare land, grassland and plateau mountain areas, but slightly lower in forest areas. This is due to the shielding effect of forest canopy on snow signal, which leads to the low snow signal in this kind of area, resulting in a certain degree of underestimation. On the whole, TM algorithm has the highest accuracy, which is because the algorithm selects endmembers by the way of classification, therefore the selected endmembers are more representative. MESMA algorithm selects endmembers in the whole image, resulting in low representation of endmembers, resulting in slightly lower retrieval accuracy than the other two retrieval algorithms.

In this paper, two surface types, forest and plateau mountain area, are selected to further illustrate the accuracy verification results of the three algorithms. The verification results of the three algorithms in forest area are shown in Figure 3, while those in plateau mountain area are shown in Figure 4.



(a) Landsat RGB and FSC result

(b)MESMA FSC (c)TM FSC (d) SI FSC

Figure 3 MESMA/TM/SI algorithms accurate verification results in Forest (20150109_148/037)

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It can be seen from Figure 3 that the validation results of the three algorithms are good, because although the forest canopy in this region blocks the snow signal, the snow signal is still strong because the forest in this region is sparse and the snow is concentrated. Further analysis shows that the retrieval results of the three algorithms are poor for the transition zone with snow and non-snow, which is due to the coarse resolution and poor performance of AVHRR sensor. At the same time, it can also be explained that MESMA algorithm and SI algorithm have a certain degree of high estimation and lack of spatial details.

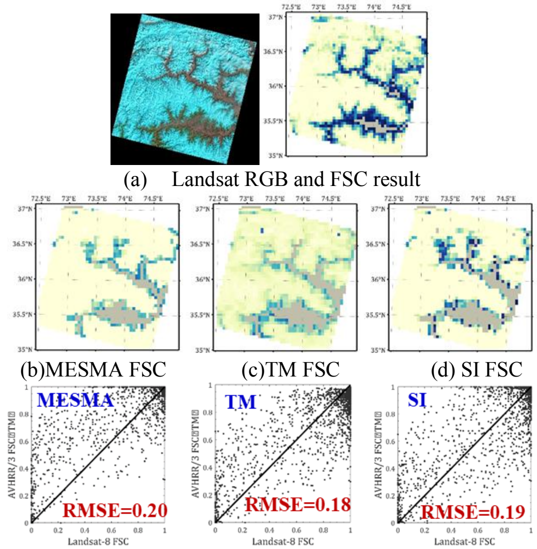

Figure 4 MESMA/TM/SI algorithms accurate verification results in Plateau mountain (20150312_150/035)

It can be seen from Figure 4 that the verification results of the three algorithms are similar to Figure 3. Although the overall accuracy is high, the retrieval results of the three algorithms are poor for the transition zone with snow and non-snow. At the same time, it can also be found that TM algorithm has a certain degree of underestimation and has rich spatial details.

5. CONCLUSIONS

In this study, we transplanted three (MESMA/TM/SI) MODIS snow cover retrieval algorithms into AVHRR sensor, then verified the accuracy in four land cover types (bare land/grassland/forest/plateau mountains) using high spatial resolution Landsat-8 images. It can be seen from the results that the three algorithms have good accuracy except for the forest area. It is also found that the three algorithms have serious underestimation in snow and non-snow transition regions. In addition, the results of MESMA algorithm and SI algorithm are similar, both of which have overestimation and missing spatial details. TM algorithm has a certain degree of underestimation but is used for rich spatial details. Finally, it can be seen from the relevant results that manual participation in sample selection can improve the accuracy but does not have universality. Since MESMA algorithm has clear physical significance, but the current endmember selection has certain limitations. In the future, the endmember selection method of MESMA algorithm will be further improved to improve the accuracy of the algorithm, then the accuracy evaluation will be carried out.

6. ACKNOWLEDGEMENTS

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