A METHOD TO IDENTIFY HIGH-QUALITY PURE SNOW DATA IN POLDER DATABASE

Jing Guo[1]*, Ziti Jiao*[1]*, Lei Cui*[1]*, Siyang Yin*[1]*, Yaxuan Chang*[1]*, Rui Xie*[1]*, Sijie Li* [1]*, Zidong Zhu* [1]

[1] State Key Laboratory of Remote Sensing Science, College of Remote Sensing and Engineering, Faculty of Geographical Science, Beijing Normal University, Beijing 100875, China

ABSTRACT

A series reflectance models for snow have been developed in recent years, but there is no trusted pure snow database to test the models yet. The Polarization and Directionality of Earth Reflectances (POLDER) BRDF data have been widely used in quantitative remote sensing community, but the recent research has revealed that an obvious wrong classification has occurred in snow POLDER BRDF database. In this study, we propose a snow index (SI) to characterize the scattering feature of snow based on RTLSRS model and develop an effective method to identify the pure snow data in POLDER database. Finally, we build a snow database with higher purity, providing a data support for model validation in the future.

Index Terms—snow, angular index, POLDER, MODIS product, RTLSRS

1. INTRODUCTION

The snow/ice is one of the most important components in cryosphere, which can make a significant difference in the study of water cycles and global energy balance. It is well known that the reflectance of surfaces is anisotropic in nature. Snow is not an exception although it is more isotropic comparing with other surfaces. This feature can be captured by angular indices. Many angular vegetation indices are now calculated using kernel-driven Bidirectional Reflectance Distribution Function (BRDF) model. Sandmeier et.al [1]have developed anisotropy factor (ANIF) which is the ratio of a radiation reflected into a specific view direction and corresponding nadir reflectance, also called relative reflectance, and anisotropy index (ANIX) that defined as the ratio between the maximum and minimum reflectance in the principal plane. These two indices are always used to study the relationship of the BRDF and the landcover. Hot-dark spot(HDS) and Normalized Difference between Hotspot and Darkspot (NDHD) was proposed by Chen et. al[2, 3] with reflectances at the hotspot and darkspot that derived from the BRDF model inversion. NDHD shows a linearity with clumping index. A structural scattering index(SSI) and a relative structural scattering index(RSSI) have been developed to distinguish different land cover types and study vegetation structures. Anisotropic Flat Index(AFX), the ratio of the white-sky albedo(WSA) to a constant for isotropic scattering (f_{iso}) in kernel-driven model, can represent the variation of BRDF, helping us for the classification [4]. Up to present, there is no available angular index for snow, but just a spectrally dependent index called Normalized Difference Snow Index(NDSI) for snow identification. It is a big challenge to find out the snow with BRDF, especially for coarse resolution data.

2. DATA AND METHOD

2.1 DATA

2.1.1 multi-angle data

POLDER was on-board the PARASOL platform launched by Center national d'études spatiales (CNES). The spatial resolution of POLDER is $6\times7km^2$ in the nadir view direction. POLDER dataset has been widely used because it can receive sufficient SZAs and VZAs. Each pixel can accumulate observations from 16 different directions at most (14 directions averagely) within a month [5].

POLDER include the measurements of 9 bands, with the central wavelengths ranging from 443nm to 1020nm. Beron et.al have built an available database for the data that obtained in 2008 [6]. First, POLDER data was corrected for atmospheric absorption and scattering, then the data that are free from cloud contamination were selected. Second, Beron et. al analyzed the 5×5 MODIS pixels centered on the POLDER with MODIS landcover product(International Geosphere-Biosphere Program (IGBP) in MCD12Q1). If the proportion of one landcover is more than 75%, the pixel was retained and the proportion was recorded as homogeneity. Third, a BRDF model was used to fit the reflectances at 670nm and computed the RMSE between the modeled values and measurements. Last, using RMSE and the number of measurements to calculate a score, which allowed for the spatial and temporal variation. Finally, 50 best pixels were selected every landcover type each month.

In this study, we utilize the snow data in POLDER database (i.e. the data marked 15 by IGBP). Totally, 600

POLDER BRDF datasets are used. These datasets are mostly located in Antarctica and Greenland, presented in the MODIS IGBP land cover map in Fig.1.

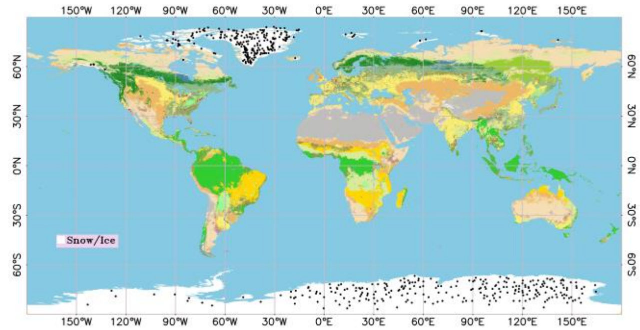


Fig.1 The distribution of global POLDER snow data

2.1.2 MCD12Q1

MCD12Q1 is a yearly landcover product, with a spatial resolution of 500m, including 5 classification schemes. Liang et al.[7] had verified that the consistency between IGBP and 30m GLC product is the best among the five schemes.

2.1.3 MOD10A2

MOD10A2 is the eight-day snow cover product, composed by the daily snow cover product. If snow cover is found in any day of the eight days, the cell is labeled snow. If there is a value appeared more than once, the value is marked with the cell [8].

2.2. RTLSRS model

Lately, Jiao et.al [9] proposed a snow kernel derived from ART model, added it to the Rossthick-LiSparseReciprocal (RTLSR) framework for a better performance to snow. The model was defined as equation (1):

$$\begin{aligned} R(\theta_i,\theta_v,\varphi,\lambda) &= f_{iso}(\lambda) + f_{vol}(\lambda)K_{vol}(\theta_i,\theta_v,\varphi) \\ &+ f_{geo}(\lambda)K_{geo}(\theta_i,\theta_v,\varphi) + f_{snw}(\lambda)K_{snw}(\theta_i,\theta_v,\varphi) \end{aligned} \tag{1}$$

where $R(\theta_i,\theta_v,\varphi,\lambda)$ is the reflectance at λ ,the kernel value of isotropic scattering kernel is 1, $K_{vol}(\theta_i,\theta_v,\varphi)$, $K_{geo}(\theta_i,\theta_v,\varphi)$ and $K_{snw}(\theta_i,\theta_v,\varphi)$ are volumetric scattering kernels, geometric scattering kernels and snow kernels, respectively, which are functions of solar zenith angle(SZA), view zenith angle(VZA) and relative azimuth angle(φ). f_{iso}, f_{vol} and f_{geo} are the spectrally dependent parameters in the model. The volumetric kernel and geometric kernel in equation (1) was RossThick function and LiSparseReciprocal function, respectively and there are no more explainations here. The snow kernel was written as:

$$\begin{aligned} K_{snw}(\theta_i,\theta_v,\varphi) &= R_0(\theta_i,\theta_v,\varphi)(1-\alpha\cdot\cos\xi\cdot\exp(-\cos\xi)) \\ &+0.4076\alpha-1.1081 \end{aligned} \tag{2}$$

The value of $R_0(\theta_i,\theta_v,\varphi)$ represents the reflectance of a semi-finite, non-absorbing media, α is a parameter to adjust the forward scattering of snow, with an optimal value of 0.3. ξ refers to the phase angle.

In this study, we set a restriction that if the model parameters are less than 0, then set it to 0, avoiding ill-posed problem.

2.3 Method

This method consists of five steps as shown in the flowchart (Fig.2). First, We find out the 13×13 MODIS pixels that lie within the POLDER, and analyze the landcover and snowcover using MCD12Q1 and MOD10A2 product, respectively. The landcover index and snowcover index was calculated as:

$$landcoverindex=N_{IGBP=15}/13\times13 \tag{3}$$

$$snowcoverindex=N/13\times13\times group \tag{4}$$

where $N_{IGBP=15}$ is the number of MODIS cells marked snow within POLDER pixel, N is the number of cells with in one month labled “200” (i.e. snow), *group* means the data acquisition frequency in a month.

Then, we count the observations in principal plane to the total and the RTLSRS model is used to invert the four weight coefficients and optimal α. The weight of determination (WoD) is calculated by three kernel values (0.189184, -1.337622 and -0.02938, respectively) and white-sky albedo (WSA). These two indices reflect the angular spatial distribution well. Next, BRDF is simulated with a given solar zenith angle of 65°. Selecting the pixels that the Nadir BRDF Adjusted Reflectance (i.e. the reflectance at 0°) is higher than 0.72 for the further processing. Last, we define the snow index (SI) as :

$$SI=ref_{-70^\circ}/ref_{70^\circ} \tag{5}$$

where the ref_{-70° and ref_{70° refers to reflectance in forward direction at 70° and backward direction at 70°, respectively. The SI can reflect the strong forward scattering of snow BRDF and regard as a index for snow identification.

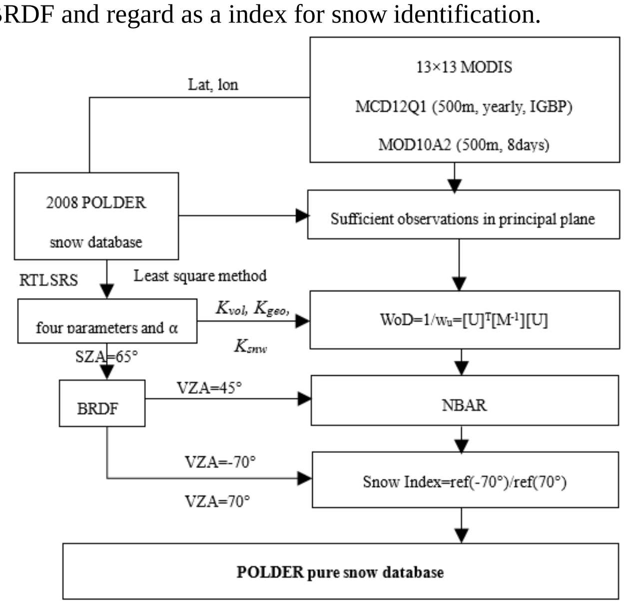


Fig.2 A general flow chart for the method

3. RESULTS

3.1 POLDER BRDF

Firstly, we use all the snow POLDER BRDF data to fit the RTLSRS model, the scatter plot is as Fig.2. The black dots represent the values appeared more frequently. We can clearly see that the BRFs are divided into two parts. There is a doubt about the part with a low value to snow. This is why we want to do the job to identify high-quality snow data from POLDER database.

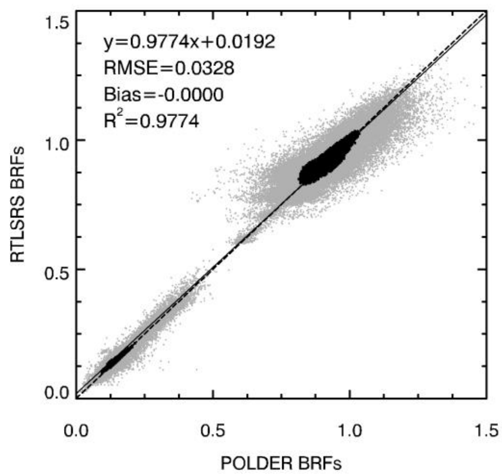
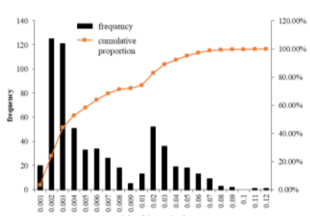


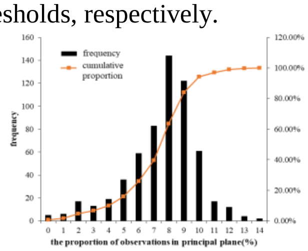
Fig.3 scatter plot for RTLSRS model fitting all POLDER snow data

3.2. The analysis of angular distribution

We figure out the proportion of observations in principal plane (including the observations within 10° around the principal plane) and the value of weight of determination, and set 5.5% and 0.015 as thresholds, respectively.



(a)Proportion of observations in PP



(b)WoD distribution

Fig.4 The statistics for angular sampling

3.3. NBAR

The reflectance of Snow is usually very high because it reflects more than 80% of the incident solar energy, especially for fresh snow. So we can identify snow preliminarily through NBAR. Only the POLDER pixels that the NBAR is higher than 0.82 are kept.

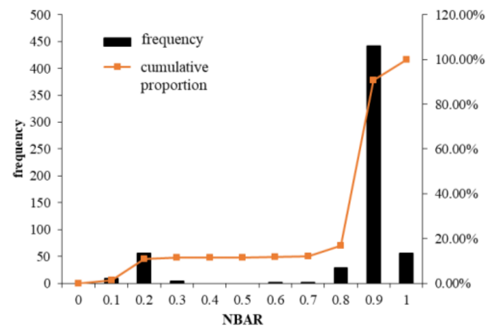
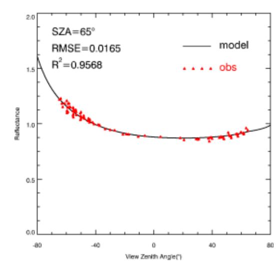


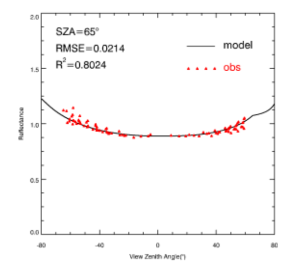
Fig.5 The statistics for NBAR

3.4. Snow Index

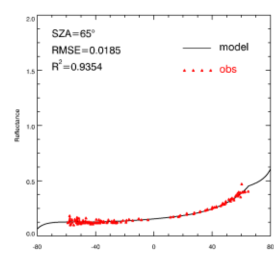
The snow index is an angular index that can recognize the characteristic of snow. We simulate all the BRDF patterns for POLDER datasets that pass the angular distribution and NBAR selection, and put the pixels with a SI that are higher than 1.15 into snow database. There are four kinds of typical BRDF curves, we use the observations at 670nm to fit RTLSRS model, the BRDF and observations in principal plane are shown as Fig.6:



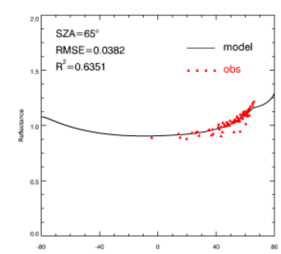
(a)a BRDF curve shows a strong forward scattering (SI>1.15)



(b) there is no obvious difference between reflectances in forward direction and backward direction (1<SI<1.15)



(c) a BRDF curve shows a strong backward scattering and with lower reflectance



(d) a BRDF curve shows a strong backward scattering and with higher reflectance (There are no observations in principal plane when SZA=65°)

(0<SI<1)

Fig.6 Typical BRDF curves for POLDER snow data

We obtain a pure snow database with 195 datasets, the results for each criterion are shown in Table1.

Table 1 selection results

Selection criteria	datasets
landcover index = 100%	511
snowcover index = 100%	316
proportion in PP > 5.5%	274
WoD < 0.015	242
NBAR > 0.82	235
SI > 1.15	195

4. CONCLUSIONS AND DISCUSSIONS

This study implement an effective method to extract high-quality pure snow data in POLDER snow BRDF database. But there are still some problems. For example, the accuracy of MODIS landcover and snowcover is not high enough for snow, and the BRDF will affected easily by rugged terrain. Also, the data obtained from November in 2005 to October in 2006 can be used to buil the pure snow database,too. Further studies will be taken with these problems.

ACKONWLEDGMENTS

This work was supported by the National Key R&D Program of China [2018YFA0605503]; the National Natural Science Foundation of China [41971288 and 41571326].

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