International Journal of Advances in Engineering and Management (IJAEM)
Volume 4, Issue 11 Nov. 2022, pp: 1215-1220 www.ijaem.net ISSN: 2395-5252

Freeze-thaw detection of Greenland ice sheet based on ant Colony algorithm

Hongquan Liu , Xingdong Wang, Yuhua Wang
College of Information Science and Engineering, Henan University of Technology, Zhengzhou 450001, China
Corresponding Author: Hongquan Liu

Date of Submission: 25-11-2022 Date of Acceptance: 06-12-2022

ABSTRACT: The freeze-thaw changes of Greenland ice sheet are of great significance to the study of global climate change.This paper is based on 19 GHz horizontal polarization data of SSM/I (Special Sensor Microwave/Image) carried by the U.S. Defense Meteorological Satellite Program DMSP.The ant colony algorithm was used to detect the freezing and thawing of the Greenland ice sheet on September 15, 2017.Firstly, the initial clustering center of the ant colony algorithm was set up to represent the pheromone, characterize the heuristic factor parameters, calculate the distance of the pixel clustering center and determine the membership degree, and then calculate the pheromone concentration for classification, calculate the class spacing of various types, determine the updating of the clustering center and carry out the freeze-thaw detection of the Greenland ice sheet.Compared with the classification results of the traditional cross-polarization algorithm (XPGR, threshold is -0.025) on the same day, the results show that the melting regions of the two algorithms are roughly similar, but the ant colony algorithm has better classification results for the regions with low gray value.Ant colony algorithm is discrete and parallel, so it is suitable to deal with the classification of such discrete numerical images. Compared with the traditional algorithm, ant colony algorithm directly performs image clustering and segmentation, so it is faster and more convenient.

KEYWORDS: Ant colony algorithm; Greenland; Ice sheet; freeze and thaw

I. INTRODUCTION

Freezing and thawing of polar ice caps play an important role in global atmospheric circulation, heat balance and climate change.The Antarctic and Greenland ice sheets make up about 97 percent of the world's glaciers and 99 percent of its total ice mass,If both melted completely, it would cause sea levels to rise by as much as 67m. Freezing and thawing of polar ice sheets would cause changes in the composition and temperature of sea water, triggering ocean currents and evaporation.In addition, changes in surface reflectance due to changes in ice sheet moisture content will affect polar radiation balance and temperature changes, thereby affecting atmospheric circulation and global water vapor transport.Therefore, freezing and thawing of polar ice sheet is a sensitive factor of global climate change, so the detection of freezing and thawing of polar ice sheet is of great significance to the study of global climate change.

There are many algorithms to analyze the freezing-thawing changes of Greenland ice sheet. It is a common method to use various algorithms to calculate the satellite image and distinguish whether the ice sheet is freezing-thawing by threshold value.Different algorithms have different advantages and disadvantages. In this paper, the ant colony algorithm is used to calculate the Greenland satellite data to find the optimal melting threshold of ice sheet freezing and thawing.The research on surface melting of ice sheet started relatively early in foreign countries. Different algorithms were used to study the changes of ice sheet freeze-thaw.Steffen et al. used normalized melt change ratio (GR) to detect ice sheet surface melting [1].Abdalat et al. used the cross ratio algorithm (XPGR) to detect the freezing-thawing changes of Greenland ice sheet [2].Anderson proposed the level difference (HR) algorithm based on PR, GR and XPGR [3].Based on microwave radiometer SSM/I and SMMR data, Joshi et al. analyzed and studied Greenland through Gaussian derivative edge detection algorithm [4].Domestic research on ice sheet freezing-thawing of Greenland is relatively late. Zhang Yan et al. proposed ice sheet freezing-thawing detection algorithm based on DVPR time series of scatterometer [5].Wang

Xingdong et al. combined the simple ice sheet freeze-thaw physical model with support vector machine (SVM) to detect ice sheet freeze-thaw [6].

Ant colony algorithm is a kind of bionic algorithm which can evolve autonomously. Since the original data are discrete digital gray image, ant colony algorithm can distinguish gray value well.In addition, the ant colony algorithm has the discreteness and parallelism, so it is suitable to deal with the classification of such discrete numerical images.Based on SSM/I data on September 15, 2017, this paper conducts freeze-thaw detection of Greenland ice sheet by ant colony algorithm, and compares the freeze-thaw detection results of Greenland ice sheet with those of XPGR algorithm.

II. STUDY REGIONS AND DATA SOURCES

2.1 Overview of Greenland

Greenland is the largest island in the world, covering an area of 2.16 million km2. It is located in the northeast of North America and between the Arctic Ocean and the Atlantic Ocean. The annual average temperature is below zero, the summer temperature in coastal areas can reach above zero, and the inland is frozen all year round.Greenland is about 2,670 km long from north to south and 1,050 km wide from east to west at its widest point. About 80% of the area of the island lies within the Arctic Circle.About 83.7% of Greenland is covered by ice and snow. The e Greenland ice sheet is about 2300 m thick on average and about 3,411 m thick at its thickest point.Greenland's total snow and ice volume is about 3 million km3, accounting for about 5.4% of the world's total fresh water.If Greenland were to lose all its ice and snow, global sea levels would rise by 7m.

2.2 SSM/I data overview

In this paper, DMSP carried special microwave imager (SSM/I) data is used, SSM/I data is widely used in polar ice and snow freeze-thaw detection.Due to the higher emissivity of high-frequency band than that of low-frequency band, 19GHz is more sensitive to melting information than 37GHz and 85.5GHz. Moreover, in the dry snow region (when the snow humidity is less than 1%), the emissivity of horizontal polarization is significantly lower than that of vertical polarization. Therefore, when the dry snow melts into wet snow, the rising trend of horizontal polarization data is more obvious than that of vertical polarization. Therefore, choosing the horizontally polarized 19GHz data can better distinguish the melting region from the non-melting region and obtain better results.And 2017 is the peak melting year among the melting cycle years.And since Greenland is located in the Arctic, the summer month of September is the peak melting month of the year, so the data of September 15, 2017 was chosen.

III. THEORETICAL BASIS

3.1 Principle of ant colony algorithm

The ants start looking for food without first telling them where it is.When one finds food, it does so by releasing a volatile secretion (called a pheromone, which evaporates over time. Pheromone concentrations indicate the distance of the path) into the environment, attracting other ants so that more and more ants find food.Instead of repeating the same path as the others, some ants will find a new path, and if the new path is shorter than the original one, gradually more ants will be attracted to the shorter path.Finally, after a while, there may be a shortest path that is repeated by most ants.

Ant colony algorithm is applied in image segmentation because any image contains parameters such as gradient, neighborhood and gray scale.The ant colony algorithm is used to segment the image. Each pixel in the image is regarded as an ant, and each pixel has its corresponding gray value within the gray scale range of 0-255.In order to find out the optimal threshold of image segmentation, the optimal threshold can be set as the food that ants are looking for, so the process of ant colony searching for food is the process of pixels with different gray values searching for the optimal segmentation threshold.

3.2 Ant colony algorithm implementation

3.2.1 The optimal threshold is solved

The optimal threshold is solved as follows ：

（1）The formula for calculating the distance d_i from each pixel point X_i to the initial threshold T from formula (1) is as follows:

$$d_i = \sqrt{(x_i - T)^2} \qquad (1)$$

（2）The pheromone concentration τ_i on the path from each pixel X_i to the initial threshold T at time t is calculated, with r as the cluster radius of the ant, let τ_i (0) as the initial amount of information, then

$$\tau_i(0) = \begin{cases} 1, & d_i \le r \\ 0, & d_i > r \end{cases} \qquad (2)$$

（3）The probability P_i of the pixel X_i to the threshold set is calculated

International Journal of Advances in Engineering and Management (IJAEM)
Volume 4, Issue 11 Nov. 2022, pp: 1215-1220 www.ijaem.net ISSN: 2395-5252

$$P_i = \begin{cases} \frac{\tau_i^{\alpha}(t) * \eta_j^{\beta}(t) *}{\sum_{x \in Z} \tau_i^{\alpha}(t) * \tau_i^{\beta}(t)}, & j \in Z \\ 0, & 其他 \end{cases} \quad (3)$$

Where, η_i is the enlightening guide function, η_i=1 / d_i, which reflects the similarity between pixels; α and β are two influence factors controlling the pheromone concentration and the heuristic guide function; Z= {X_z | d_z ≤r, z = 1,2,..., N} is the set of paths.

（4）Get the latest threshold

When P_i is less than P_0 (P_0 is the weight probability factor), the pixel X_i is grouped into the new threshold set. C_j represents all data sets grouped into within the new threshold domain.C_j = ｛X_i | d_i ≤ r , I = 1,2,…,J ｝ . The new threshold $\bar{T}$ is:

$$\bar{T} = \frac{1}{j} \sum_{i=1}^{J} X_i \quad (4)$$

(5) Update the pheromone concentration of each path

After one cycle, the pheromone on each path changes. In order to improve the global optimization ability and reduce the convergence speed of the algorithm, the method of adaptively changing pheromone concentration is proposed as follows:

$$\tau_i(t) = \left(1 - \frac{n}{m}\rho\right) * \tau_i(t) + \rho\angle \quad (5)$$

Where ρ is the coefficient of pheromones changing over time; n is the number of pixels at d_i≤r; m is the total number of all pixels; and $\Delta\tau_i$ is the increment of pheromones on the path after a loop.

3.2.2 Set the end algorithm condition

Ant colony algorithm is an algorithm that needs an appropriate number of cycles. If the number of cycles is too small, the optimal threshold will not be obtained. If the number of cycles is too large, a lot of time will be wasted and the efficiency will become low.The method of equation (6) can control the number of cycles automatically applied to the appropriate range.

$$|T - \bar{T}| \leq e \quad (6)$$

Where, e is a constant and its value is 0.01. When the set conditions are met, the algorithm can obtain the optimal solution.

3.2.3 Parameter Initial value setting

In the ant colony algorithm in this paper, α and β are the parameters representing the pheromone and the importance degree of the heuristic factor respectively, ρ is the membership degree of the ant colony algorithm. These three parameters determine the convergence speed of ant colony algorithm to find the optimal threshold and the performance of search path.Considering the influence of the neighborhood, gray level and gradient of the Greenland ice sheet freeze-thaw data image on the fuzzy clustering function of the ant colony algorithm, after several debugging, the initial values of α and β are set to a large range of 2 and 4 respectively, so that the membership ρ of the target boundary background and noise obtained by the integrated pixel features is the best.

IV. ICE-SHEET FREEZE-THAW DETECTION BASED ON ANT COLONY ALGORITHM

The basic steps of ice sheet freeze-thaw detection based on ant colony algorithm are as follows:

（1）Set the initial value of each basic parameter: α parameter set to 2, β parameter set to 4, c parameter set to 210.

（2）d_i which is calculating the distance from X_i to the initial cluster center c according to Equation (1), if d_i is zero, the membership of the pixel to the class is 1, otherwise, the boot function is calculated according to Equation (4), and the amount of information from X_i to each path according to Equation (5).

（3）The pheromone concentration of each path is calculated by setting τ_i (0) as the initial information quantity, and the pheromone concentration on the path from each pixel X_i to the initial threshold T at time t is τ_i.

（4）The membership degree of pixels is calculated according to equation (3) to determine whether the membership degree is greater than P0. If so, the information quantity increment $\Delta\tau_i$ is calculated according to equation (5) to update the information quantity. Update the Class J cluster center as per Equation (4). Otherwise, the C_j set where C_j represents all data sets grouped within the new threshold domain.

（5）Calculate the inter-class distance for each class. When the class spacing is less than the threshold value e, the two classes are merged into one class and the clustering center is updated.

（6）If the class spacing is greater than the threshold value e, it is the pixel to be classified, return to the second step, otherwise the end. The specific implementation process of ice sheet freeze-thaw detection based on ant colony algorithm is shown in Figure 1, where T represents the initial threshold.

International Journal of Advances in Engineering and Management (IJAEM)
Volume 4, Issue 11 Nov. 2022, pp: 1215-1220 www.ijaem.net ISSN: 2395-5252

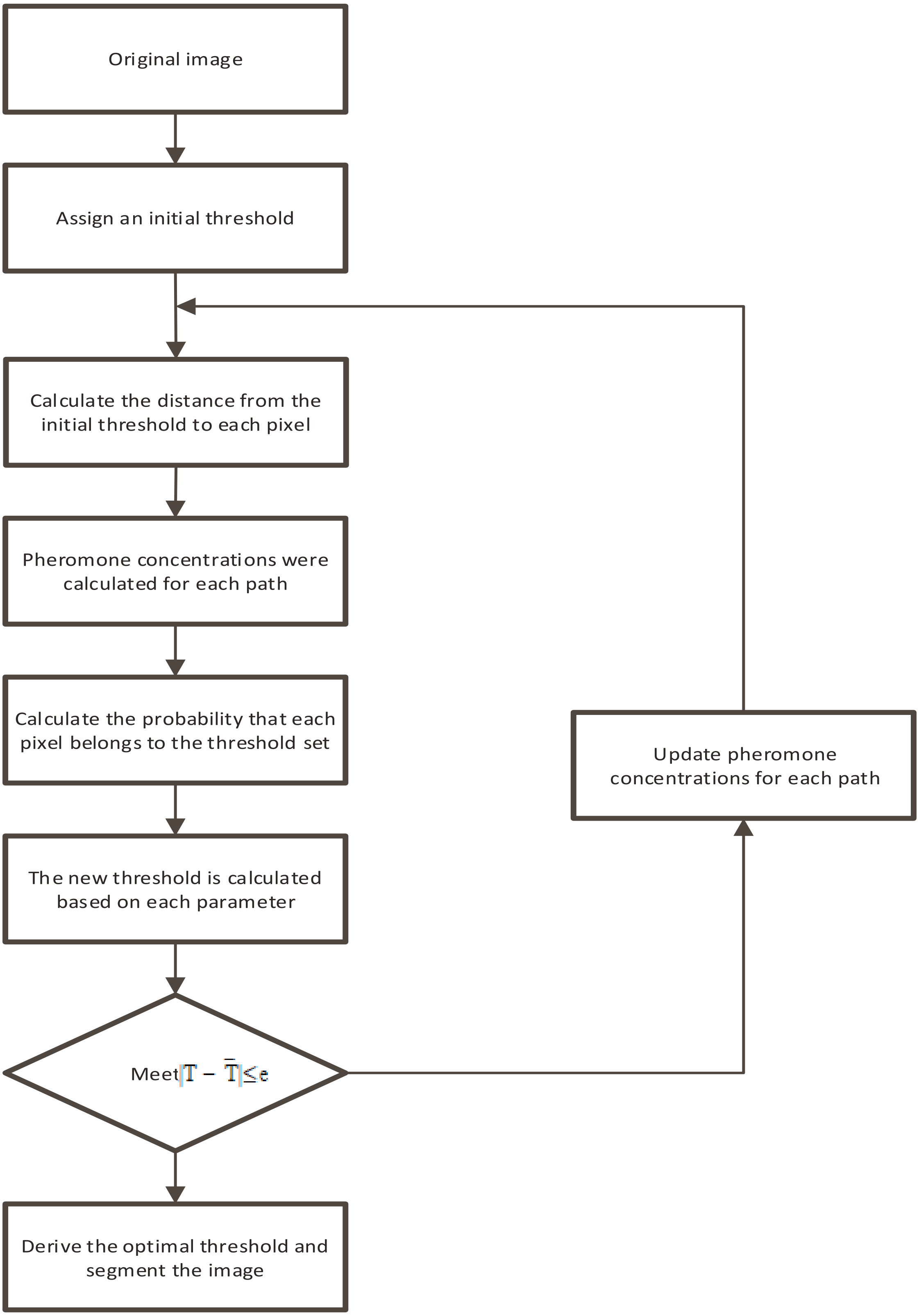

Figure 1 freeze-thaw detection process of ice sheet based on ant colony algorithm

The Greenland freeze-thaw classification results obtained using the ant colony algorithm are shown in Figure 2. The results of Greenland ice sheet based on XPGR algorithm are shown in Figure 3.

International Journal of Advances in Engineering and Management (IJAEM)
Volume 4, Issue 11 Nov. 2022, pp: 1215-1220 www.ijaem.net ISSN: 2395-5252

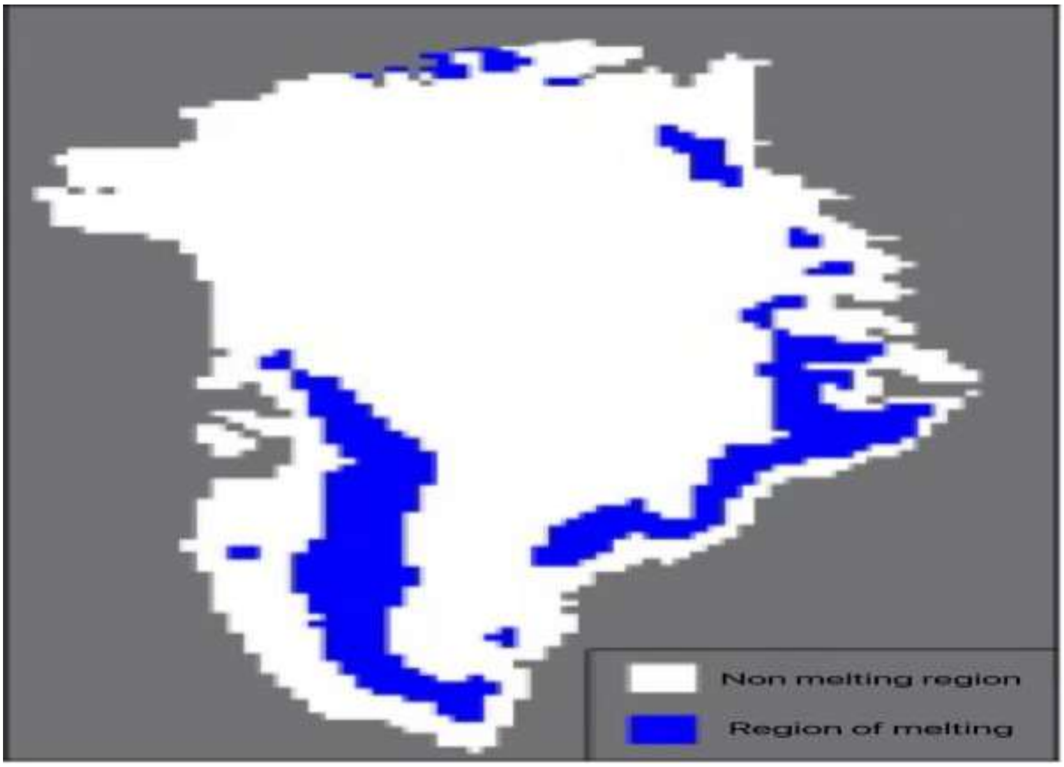

Figure 2. Results of the X P G R algorithm

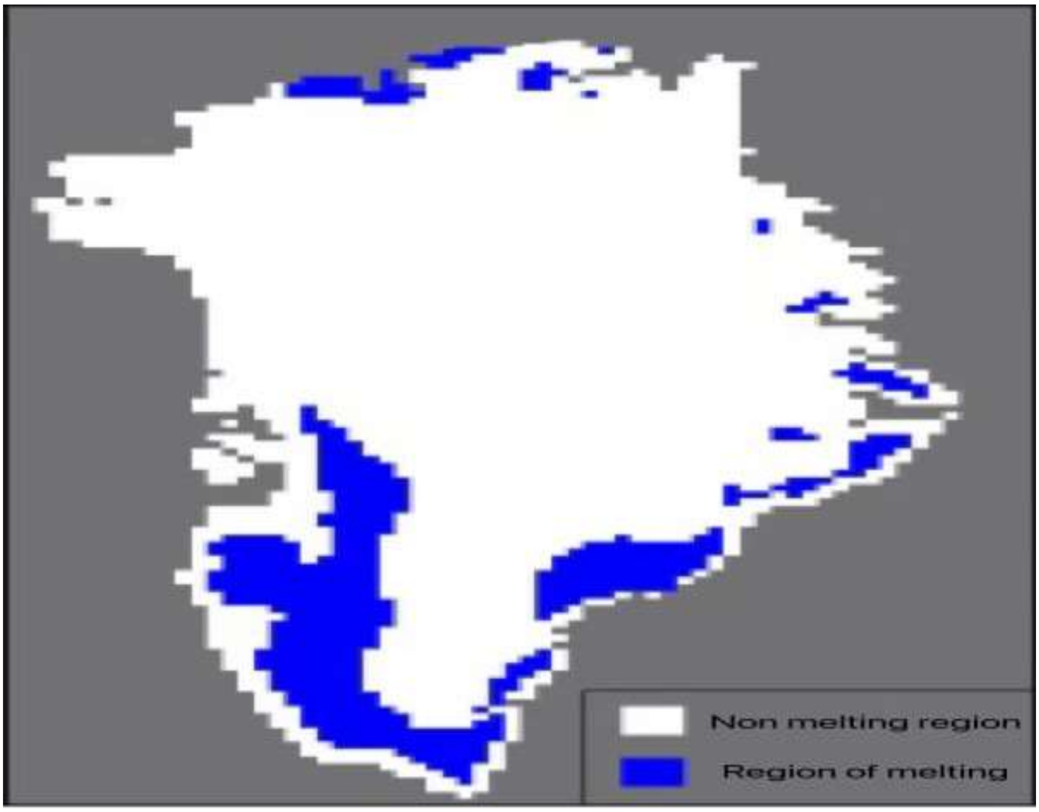

Figure 3 Results of the ant colony algorithm

V. CONCLUSION

In this paper, ant colony algorithm is applied to the freezing and thawing detection of Greenland ice sheet. The freezing and thawing detection results of Greenland ice sheet based on SSM/I data on September 15, 2017 are obtained and compared with XPGR algorithm.The results show that the melting regions of the two methods are similar in general, and the results based on the ant colony algorithm have better detection results for the regions with low gray value.Since the original data are discrete digital images, and the ant colony algorithm has both discrete and parallel characteristics, the classification of such discrete numerical images fits well. Moreover, compared with the traditional threshold algorithm, the ant colony algorithm is faster and more convenient.

REFERENCES

[1]. Steffen, K; Abdalati, W; Stroeve, J; 1993, “Climate Sensitivity Studies of the Greenland IceSheet Using Satellite AVHRR, SMMR, SSM/I and in Situ Data”. Meteorologyand Atmospheric Physics. 51 (3-4): 239-258.
[2]. Abdalati, W; Steffen, K; 1995, “Passive microwave-derived snow melt regions on the Greenland Ice Sheet”. 22(7):787-790.
[3]. Anderson, M-R; 1997, “Determination of a Melt-onset Date for Arctic Sea-ice Regions Using Passive-microwave Data”. Annals of Glaciology. 25: 382-387.
[4]. Joshi, M; Carolyn, J-M; Kenneth, C-J, et al. 2001, “An edge detection technique to estimate melt duration, season and melt extent on the Greenland Ice Sheet using Passive Microwave Data”. 28(18):3497-3500.
[5]. Zhang, Y; Li X-W; Liang, L; 2017, “Study on freeze-thaw detection of Greenland ice sheet based on microwave scatterometer”. Remote sensing technology and application, 32(01):113-120.
[6]. Wang, X-D; Duan, Z-Y; Wand, C; 2017, “Freeze-thaw detection of Greenland ice sheet based on physical model and SVM”. Journal of Xi 'an University of Science and Technology,37(06):912-918.