CHARACTERISTICS OF VEGETATION COVER, ROUGHNESS AND ALBEDO DISTRIBUTION OVER CHINA*

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ABSTRACT

To build land surface dataset for climate model, with application of remote sensing technique as well as the Geographic Information System (GIS), the data of surface type, roughness and albedo over China in 1997 were retrieved, resolutions being 10 km × 10 km. Based on these data, an analysis is conducted on the geographic distributions and seasonal variations of surface vegetation cover and roughness as well as albedo over China. Results show that surface vegetation cover is mainly located to the south of Yangtze River, in Southwest and Northeast China and sparse vegetation cover is in the Northwest. The variation of land surface cover affects the variations of land surface roughness and albedo. High albedo occurred in the north of Xinjiang Autonomous Region, the north of Northeast China and the Qinghai-Xizang Plateau in winter, in correspondence with the location of snow cover.

For most part of China, surface roughness decreases and albedo increases in winter, while the roughness increases and the albedo decreases in summer, which could mainly result from land surface cover (snow cover and vegetation cover) and soil moisture changes. This shows that the geographic distribution and seasonal variation of the albedo are almost opposite to those of the roughness, in agreement with theoretical results. Temporally, the amplitude of surface roughness change is quite small in comparison with the roughness itself.

Key words: vegetation cover, albedo, roughness, characteristics

I. INTRODUCTION

During recent years, more and more attentions have been paid to the land surface processes in climate simulation and research. However the distribution of surface type, roughness and albedo are the most important parts of land surface processes, and their distribution statuses and variations directly affect the exchanges of energy and momentum as well as moisture fluxes between land and atmosphere (Li and Zhang 1993). To analyze

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and research these physical factors is not only the foundation of climate simulation but also helpful for further understanding of the characteristics of climate change and distribution over China.

As for landuse data, some have been obtained by observation such as surface albedo. But there are still some which have been less studied such as surface cover type, surface roughness etc. Although much work has been done on research and observation for the albedo, the conventional means of obtaining the albedo is only by isolated observation. In the case that there are much fewer observation stations, the results by this method to some extent may differ from the reality, especially for the Qinghai-Xizang Plateau where the topography is complicated, altitude varies dramatically, land surface feature changes a lot, and few radiation observation stations are established. Therefore it is more practical to retrieve ground albedo with remote sensing technique. Also, it is objective to retrieve the distributions of vegetation types and surface roughness with the technique.

II. METHOD OF OBTAINING DATA

Based on the China resource dataset with scale of 1:4 million, from the Information Office of Geography Institute, China Academy of Sciences, firstly a classification of constant snow cover and desert regions over China was made according to the China Satellite Image Map (Huang 1995), then the sub-classification of snow cover, no vegetation cover or sparse vegetation cover regions was carried out with remote sensing technique using NOAA-AVHRR data in 1997, and finally the monthly background map of land surface type was produced with resolution 10 km × 10 km after geometrical correction, verification and superposition. Further correction of the retrieved data with China phenograms (Zhang et al. 1995) as well as other related data retrieved monthly distributions of vegetation over China in 1997.

Surface roughness is a very complicated physical element, computed using different methods for different types of vegetation distributions from the angle of practical application. For crop, the roughness length (Z_0) is calculated using the formula by Monteith (1973) proposed after the research on crop:

$$Z_0 = 0.125h_0, \tag{1}$$

where h_0 is the crop height related with its growth status.

To date, it is very common to estimate plant growth status in large area using remote sensing technique, but there are still few models available. For forest land, we take the formula of computing surface roughness (Z_0) proposed by Jarvis (1976):

$$Z_0 = 0.075h_1, \tag{2}$$

where h_1 is the canopy height, taken as statistic height.

The roughness of land surface with almost no change all the year round is represented by experimental data. For instance, the roughness of water is taken as 0.0024 m, desert 0.05 m, semi-desert 0.1 m, ice/snow and bare land 0.01 m (Fu et al. 1994; Dickinson et al. 1986).

The value of surface albedo is related with ground moisture, color, structure etc. According to the approximate calculation approach of retrieving climate surface albedo proposed by Sun and Weng (1994), the average surface albedo can be expressed as

$$\overline{A} = \frac{\sum_{i=1}^{n} A_i E_i}{\sum_{i=1}^{n} E_i}, \tag{3}$$

where A_i and E_i are the albedos in different spectrum areas and incident radiation reached the surface respectively. E_i can be determined by radiation model. The filtered albedos of A_1 and A_2 for visible light of Channel 1 (0.58—0.68 μm) and the near-infrared light of Channel 2 (0.725 — 1.10 μm) can be obtained from NOAA-AVHRR data. When the incident radiation reached the surface from the other spectrum areas and albedos are considered as the function of A_1 and A_2. Formula (3) can be written as

$$\overline{A} = X_1 A_1 + X_2 A_2. \tag{4}$$

According to the research results by some scientists (Brest et al. 1987), there exists relationship between the albedos for the incident radiation reached the surface from the other spectrum areas in the total incident radiation and the filtered albedos from Channels 1 and 2. Thus X_1 and X_2 in Eq. (4) can be deduced, and the albedos for different kinds of land surfaces can be calculated.

III. CHARACTERISTICS OF VEGETATION COVER OVER CHINA

Distribution of land surface or vegetation type coverage plays an important role in the exchanges of energy, momentum and moisture between land and atmosphere. Until now, most of data exist as the forms of vegetation map and satellite image, and few data are available for China numerical research on land surface processes, therefore it is necessary to retrieve the data of vegetation type cover over China. For different purposes, there are different methods to classify vegetation type, for instance, for the research of ground and global albedo (Hummel and Rack 1979) and for the research of carbon dioxide question (Watts 1982). For use of climate model, in this paper, 20 kinds of surface vegetation types (except ocean) over China are grouped as (1) lakes, (2) evergreen needle leaf tree, (3) deciduous needle leaf tree, (4) evergreen broad leaf tree, (5) deciduous broad leaf tree, (6) evergreen shrub, (7) deciduous shrub, (8) grassland, (9) withered grassland, (10) bog or marsh, (11) cold-resistant mixed crop, (12) temperate mixed crop, (13) irrigated subtropical mixed crop, (14) dry subtropical mixed crop, (15) tropic mixed crop, (16) desert, (17) semi-desert, (18) bare land, (19) sparse plant land, (20) snow/glacier.

Figure 1 demonstrates the vegetation covers of January and July 1997 over China respectively (figures omitted for the other months). As shown in the figure, there exists obvious seasonal change of land surface type cover for most of the Northwest, the Qinghai-Xizang Plateau and the Northeast. In winter, the region of Northwest China is dominated by bare land and snow (in the north of Xinjiang), and the Qinghai-Xizang Plateau is covered by withered grass, deciduous shrub and snow, and most part of Northeast China is dominated by snow, bare land, withered grass and deciduous needle leaf woods. We can see that, with the coming of summer, in most areas grows sparse vegetation out of bare land from winter, meanwhile snow accumulated in winter melts rapidly in the north of Xinjiang, the west of the Qinghai-Xizang Plateau, the vicinity of Da

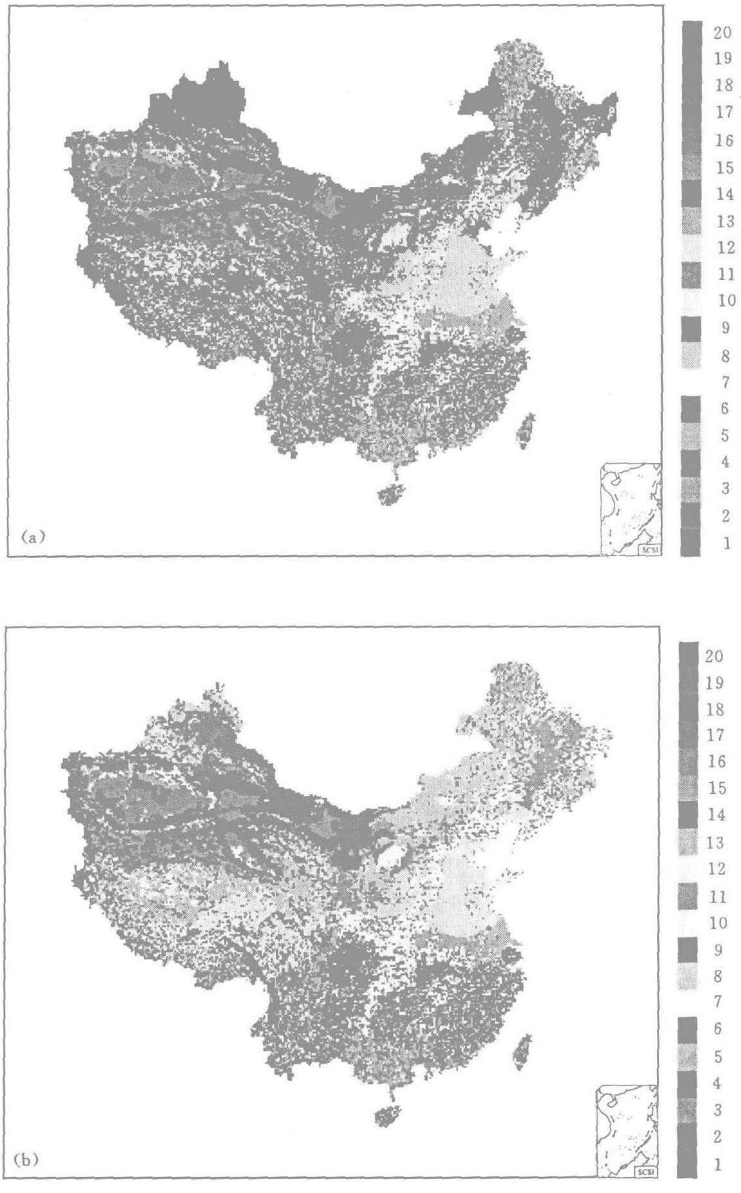

Fig. 1. Vegetation cover over China: (a) January and (b) July.

Hinggan Mountains and Changbai Mountains. In most areas of Northwest China grows sparse vegetation. Southwest China mainly consists of deciduous shrub, grass land and marsh, and the Northeast mainly the deciduous needle leaf woods, deciduous shrub. It can be seen from subsequent analyses that the seasonal change of land surface type affects the surface albedo and roughness.

As known in Fig. 1, the land surface type in the Southeast China seasonally changes less. Most areas to the south of the Yangtze River are covered by evergreen needle leaf trees and evergreen shrub all the year round, the covered area almost is in agreement with the geographic location of the mountains. The vegetation type coverage is well-distributed in Sichuan Basin. the Plain in the middle-lower reaches of Yangtze River and the North China Plain.

IV. CHARACTERISTICS AND SEASONAL VARIATION OF SURFACE ROUGHNESS

Figure 2 gives the distributions for monthly surface albedo over China in January 1997 and the difference between the averages in July and January. When the same representing contours are used as in Fig. 2 to draw the map of monthly roughness distribution in July. the pattern of roughness distribution for July will be the same as that in January as in Fig. 2a. This indicates that the seasonal change of roughness can not change the general geographic distribution pattern of the roughness. This also shows that the amplitude of roughness seasonal change is less than the roughness itself.

As shown in Fig. 2a. high roughness mainly appears in the Northeast. the Southwest (except Sichuan Basin) and South China. and low value appears in the Northwest. the Inner Mongolian Plateau. the Northeast Plain. the North China Plain and Sichuan Basin. This kind of roughness distribution is obviously related with the complexity of topography and the status of vegetation growth. There are mountains with luxuriant trees in the Northeast, the Southwest. therefore greater surface roughness occurs over there. In the Northwest. most of land surface is occupied by desert. sparse vegetation area or bare land. vegetation cover is less than that in the south of China. as a result. land surface roughness is much lower in comparison. Vegetation cover is less in the regions in the Inner Mongolian Plain. the Northeast Plain. the North China Plain. Sichuan Basin. etc. Thus land surface roughness is lower than that in the other regions of China.

As shown in Fig. 2b, from January through July, surface roughness increases obviously in the regions of Northwest China, the North China Plain. Sichuan Basin. the Plain in the middle-lower reaches of Yangtze River. etc. As known in the distribution of vegetation cover (Fig. 1). withered grass and bare land dominate the most part of the Northwest China in winter. but become covered by sparse vegetation in summer. and the roughness increases obviously due to the obvious seasonal difference of land surface cover type. Similarly. surface vegetation grows fast in the regions such as the North China Plain, Sichuan Basin. the Plain in the middle-lower reaches of Yangtze River. etc.. in summer due to farming. the roughness increases obviously.

Generally speaking, the distribution of surface roughness is directly related with topography and the conditions of vegetation cover, their relationship can be seen from the figure of vegetation cover distribution over China (Fig. 1). Since the topography is complicated and vegetation grows lushly in South China. the Southwest and Central China as well as the most part of Northeast China. the surface roughness is high. While the topography is smooth in Sichuan Basin. the Plain in the middle-lower reaches of Yangtze River, the North China Plain and the Northeast Plain. thus surface roughness is small. and vegetation cover is sparse in the Northwest. thus surface roughness is also small. As known from above, the seasonal change of surface albedo directly reflects the status of vegetation growth and of surface cover. Air temperature is higher in spring, summer and fall, good for vegetation growth. and surface roughness increases; while air temperature is lower in winter. hard for vegetation growth. therefore surface vegetation cover becomes

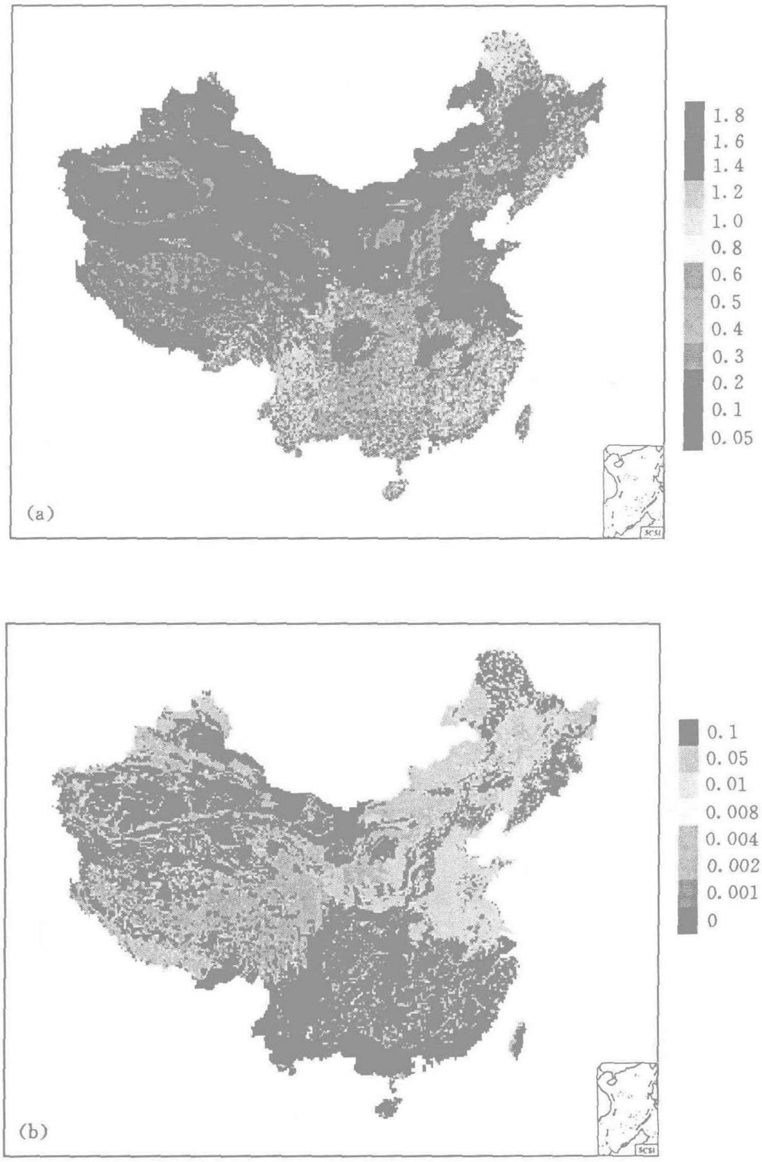

Fig. 2. Distribution of average roughness: (a) January and (b) difference for July to January.

less, furthermore, snow cover makes the land surface become smoother, thereby surface roughness reduces.

V. CHARACTERISTICS OF ALBEDO DISTRIBUTION AND ITS SEASONAL CHANGE

From the monthly average distribution of surface albedo, one can note that, there are different characteristics of surface albedo distributions in different seasons. In winter (Fig. 3a), higher surface albedo occurs in the north of Xinjiang Autonomous Region, the Qinghai-Xizang Plateau, the north of Da Hinggan Mountains and the northwest and the east of Heilongjiang Province, basically in accordance with the location of snow cover

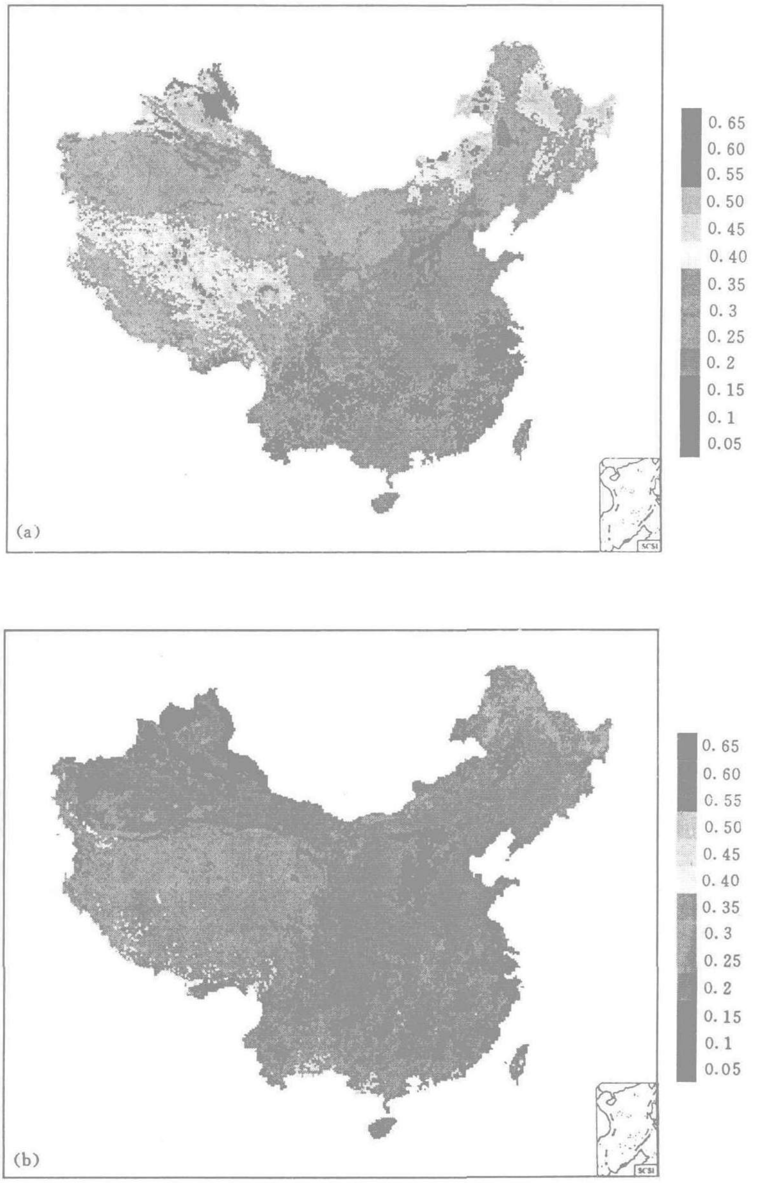

Fig. 3. Distribution of surface albedo average over China: (a) January and (b) July.

region. This indicates that the status of surface albedo is directly related with the snow cover in winter. Smaller albedo is in the southeast part of China.

Surface albedo commonly decreases over China in summer (Fig. 3b) in comparison with that in winter, where the obvious reduction occurred in the Northwest (the north of Xinjiang), the Qinghai-Xizang Plateau and the Northeast, the amount of reduction is greater than 0. 2, probably related with the snow melt in this region. In summer, higher surface albedo dominates the Qinghai-Xizang Plateau with topography of higher altitude in the Southwest, but its value is less than that in winter, probably due to the still existed snow cover over some high mountains. Compared with that in winter, surface albedo slightly increases in the southernmost part of the South China in summer, in agreement with the results obtained from traditional observation (Weng 1997). This phenomenon may result from the reduction of soil moisture.

Characteristics of surface albedo distribution in spring are similar to those in winter, and the characteristics in fall are similar to that in summer. Their values are between that in winter and in summer. This is related with the status of vegetation growth and the status of soil moisture.

From albedo yearly average (figure omitted), the highest value of surface albedo occurs in the Northwest and Northeast regions, about 0. 35; the lowest value occurs in Southwest China's Sichuan Basin, less than 0. 15. As shown in Fig. 3, above-mentioned high albedo could result from snow cover over the region in winter.

Generally speaking, the retrieved distribution of surface albedo over China using remote sensing technique is in agreement with that obtained from surface radiation measurement by conventional means (Weng 1997), but the geographic distribution of the retrieved surface albedo is described in detail.

VI. SUMMARY

From above-mentioned analysis, one can note that, vegetation cover is mainly located in Southeast, Southwest and Northeast China. Sparse vegetation cover is in the Northwest. Great seasonal change of snow cover occurred in the North.

Surface vegetation cover and its type change directly affect the status of surface roughness. High surface roughness is mainly located in the South, the Southwest and the Northeast, and low roughness is mainly located in the Northwest, the North China Plain, the Northeast Plain, Sichuan Basin and the Plain in the middle-lower reaches of Yangtze River. Temporally, for most part of China, surface roughness increases in summer and decreases in winter, but the amplitude of the change is very small in comparison with surface roughness itself.

Surface coverage also affects surface albedo. The seasonal change of surface snow cover can cause obvious change of surface albedo. High albedo occurred in the north of Xinjiang Autonomous Region, the Qinghai-Xizang Plateau and the Northeast China in winter, in correspondence with the location of snow cover, and the low value occurred in Southeast China. In summer, surface albedo decreases in comparison with that in winter, in which there exists obvious decrease of albedo in the north of China. High albedo is located over the Plateau in summer, but less than that in winter.

Surface roughness decreases and surface albedo increases for most parts of China in winter, which could be related to that there is less vegetation covers, more ice and snow covers in winter. While the roughness increases and albedo decreases for most parts of China in summer, which could also result from that vegetation cover and soil moisture changes in summer.

Although there are many factors affecting the albedo, such as surface roughness, snow coverage, soil moisture and so forth, the geographic distribution and seasonal variation of the albedo are almost opposite to those of the roughness. As for their relationship, some references have mentioned about it (Weng et al. 1979), that is, when the roughness increases, the albedo could decrease. This feature has been demonstrated from the results of the retrieved roughness and albedo by remote sensing technique.

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