Estimation of Vegetative Surface Albedo in the Kushiro Mire with Landsat TM Data ---A New Approach in Atmospheric and Spectral Corrections---

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Abstract

A method has been developed for estimating the filtered narrow band surface albedo using Landsat/TM data. The surface albedo from the filtered range of Landsat/TM is converted to the surface albedo with unfiltered spectral range. The atmospheric effects on each channel are systematically different, because of the different spectral behavior of the atmospheric parameters. As a result, in this study, atmospheric correction has been done in different parameters for visible and infrared channels respectively. The surface albedos of the Kushiro Mire gotten with this method were compared with the observed data in the Kushiro Mire. The results show that the satellite inferred albedos agree well with the diurnal mean of ground observed albedos (with a 3% systematic error). There is a seasonal variation of albedo in the high and low mires, the albedo decreased gradually from April to July and reached its minimum in July, and then it rose gradually from August to October. It is also clear that there is a characteristic pattern of surface distribution according to the vegetation types of this area. The average surface albedos of each type of community are 0.164 for *Sphagnum*, 0.175 for *Carex*, 0.179 for *Pragmites* and 0.177 for *Alnus*. In other words, the albedo in high mire (mainly covered by *sphagnum*) is lower than in the low mire (mainly covered by *phragmites* and *carex*).

Key words : Albedo, Spectral behavior, Atmospheric and spectral corrections, Mire.

1. Introduction

Nowadays, remote sensing techniques have been applied in meteorology, oceanography, hydrology and some other scientific fields, and have become a useful method for monitoring a vast region. Monitoring with a satellite remote sensing has many advantages in collecting data continuously, regularly and repeatedly in a large area, in particular in a vast wetland where the field investigation is very difficult. Therefore, remote sensing with satellite data is the most suitable method for surveying in this kind of region.

The purpose of this study is to develop a new method for estimating the unfiltered surface albedo with Landsat TM data, and to analyze the vegetative albedo distribution on Kushiro Mire. Further, the albedo estimated from satellite data was compared to the albedo observed in the mire using an albedo meter.

2. Regional Description

The Kushiro Mire is located near Kushiro City in the East Hokkaido, and faces the Pacific Ocean on the Southward of the mire. The other three sides of it are surrounded by steep slopes of hills and marine terraces that are lower than 140m. Configuration of the mire is very complex because the fringes expand outward along the rivers. The main area of the mire is 10--13km in the latitudinal direction and about 18km in the longitudinal direction. Land surface of the Kushiro Mire is very flat and the altitude is lower than 10m above mean sea level in all areas.

3. Methods

Using the principle of this study, the field observation and satellite observation must be carried out at the same time. The field observations were carried out from 24 June to 4 August 1993 and from 24 April to 31 December 1994. The Landsat TM data for only 21 May 1984 and July 1993 were analyzed, because the foggy and cloudy weather limited the remote sensing.

3.1 Method for Atmospheric Correction

To make atmospheric corrections from the satellite data, a linear relation between a clear-sky planetary albedo and a surface albedo was developed by Chen and Ohing(1984) based on Lacis and Hansen's(1974) parameterization. This relation was modified by Nakagawa(1992) for NOAA AVHRR data in Antarctica. and for Landsat MSS data in Shizuoka Prefecture to obtain the filtered surface albedo from the filtered planetary albedo. The atmospheric effects on each satellite channel are systematically different, because of the different spectral behavior of atmospheric parameters. As a result, in this study, atmospheric correction has been done respectively in different

parameters for visible and infrared channels.

3.2 Method for Spectral Correction

Tani(1990) estimated evapotranspiration and heat balance in an agricultural land and a forest area with NOAA AVHRR data applying the method of spectral correction based upon the atmospheric transmittance/radiance model(Knezy et al.1980). In this study, the coefficients are modified to be suitable for Landsat TM data.

3.3 The flow chart of analysis

The flow chart of analysis is shown in Fig.1. In order to make the program simple and fast, the geometric processing was done as the first step. Then atmospheric and spectral corrections were made in proper order. In order to check the accuracy of the vegetative surface albedo estimated from satellite data, field observations were carried out in the Kushiro Mire. The field data were also analyzed to consider the relationship of the surface albedo to precipitation and the groundwater condition.

Fig.1 Flow chart of analysis

4. Results and Discussion

4.1 Results of Field Observation

A comparison of surface albedo between the high and low mires was conducted (Fig.2). The changing range of albedo in high mire is smaller than in low mire. However, from late September to early October, the opposite result was obtained, possibly because the groundwater level in the high mire was higher than the ground surface due to the continual precipitation and the water surface exposed to air. The low mire was also higher than the groundwater level but the high vegetation canopy concealed the water surface from the albedometer. Two remarkable high values

on 30 April and 1 May both in the high and low mire, were caused by the snowcover on these two days.

Fig.2 The Relationships among Albedo, Precipitation and Groundwater Level in the High and Low Mire

There is a remarkable seasonal variation of albedo in high and low mire. In May and June, the height of vegetation in the Kushiro Mire is still low, the albedo is affected easily by the condition of ground surface. The albedo thus fluctuates rather more than in summer. In July and August, the vegetation grows luxuriantly, thus the albedo depends most on the surface of vegetation, and the influence of the ground surface condition became very small. So its fluctuation was not so large. In September and October, the fluctuation of albedo is greatest because of the continual rain as described above.

4.2 Results of Estimation with Landsat TM data

To assess the reliability of the calculated value of albedo, the derived regression equation was tested by comparing the satellite-inferred and ground-observed values in the Kushiro Mire.

The vegetative surface albedo in the Kushiro Mire was estimated from Landsat TM data which was received on 21 May, 1984 and 1 July, 1993. A clear relation was seen between surface albedo and vegetation type: The average surface albedos of each community on 21 May 1984 are 0.199 for *sphagnum*, 0.207 for *carex*, 0.204 for *phragmites* and 0.207 for *alnus*. On 1 July 1993 they are 0.164 for *sphagnum*, 0.175 for *carex*, 0.179 for *phragmites* and 0.177 for *alnus*. It is clear that the albedo of *phragmites* and *alnus* are larger, *carex* is in the middle and *sphagnum* is the smallest. This result agrees with the field observations. The albedo in May is higher than that in July, and this difference was also obtained from field observations.

The comparison between the estimated and observed albedos is shown as Fig.3. On July 1, the estimated albedos agree with the observed albedos because the field observations and satellite observations were carried out at the same time, the errors are 1.09% for the high mire, 3% for the low mire. The lack of field observation on 21 May 1984, forces us to compare the estimated albedo on 21 May 1984 with the observed albedo in May 1994. The result shows that the estimated albedos are all lower than the observed values, the errors are 9.05% for the high mire and 11.5% for the low mire. In order to understand the reason, the meteorological data of snowfall in the mountainous region around the Kushiro Mire were collected from November 1983 to April 1984 and from November 1993 to April 1994. The result shows that the greatest snow depth was recorded in two periods: 96cm at Shibecha and 55cm at Tusrui in March 1984; 47cm at Shibecha and 49cm at Tusrui in March 1994. At Tusrui, the maximum snow depth was equal in the two periods, whereas at Shibecha, the maximum snow depth in March 1984 was about twice that in March 1994. This indicates that the snowmelt water flow into the mire in May 1984 was likely to be larger than that in May 1994, and the groundwater level in May 1984 was higher than that in May 1994. Thus the calculated albedo in May 1984 is lower than the observed value in May 1994.

Fig.3 The Comparison of Estimated and Observed Value (the white is the albedo from the high mire, the black is the albedo from the low mire)

A distribution map of the vegetative surface albedo has been done. These results will be useful for monitoring the vegetative and climatic environments of the Kushiro Mire, especially for estimating the heat and water balance of the whole area of the mire.

5. Conclusion

- (1). The surface albedos obtained from this method have a good agreement with the diurnal mean of ground observed albedos, with a 3% systematic error.
- (2). The albedos in high and low mire are closely related to the groundwater level.
- (3). The albedos in the high mire are lower than that in the low mire.
- (4). From spring to winter, there is a remarkable seasonal variation of albedos in high and low mire.

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References

- Chen, T.S and Ohing, G., 1984: On the relationship between clear-sky planetary and surface albedos. *J. Atmos. Sci.*, 41, 156-158.
- Kneyzys, F.X., et al., 1980: Atmospheric Transmittance/Radiances; Computer Code Llowtrang, AFGL-TR-83-0187, Air Force Geophysics Laboratory, pp.200.
- Koepke, P., 1989: Removal of atmospheric effects from AVHRR albedo, *J. Appl. Meteorol.* 28, 1341-1348.
- Lacis, A.A. and Hansen, J.E., 1974: A parameterization for the absorption of solar radiation in the earth's atmosphere. *J. Atmos. Sci.*, 31, 118-133.
- Liou, K.N. and Sasamori, T., 1975: On the transfer of solar radiation in aerosol atmospheres. *J. Atmos. Sci.*, 32, 2166-2177.
- Liou, K.N. and Sasamori, T., 1983: Direct determination of surface albedos from satellite imagery. *J. Climate Appl. Meteorol.*, 22, 530-536.
- Nakagawa, K., 1992: Estimation of surface albedo distribution in Lutzow-Holm bay and its neighborhood with NOAA/AVHRR data *Proc. NIPR Symp. Polar Meteorol. Glaciol.*, 6, 1-15
- Thekaekara, M.P. and Drummond, A.J., 1971: Standard values for the solar constant and its spectral components. *Nature (London), Phy. Sci.*, 229, 6-9.