Proceedings of ISAP'04, Sendai, JAPAN

Study on the Forest Observation in Kushiro Wetland by using Pi-SAR data

Kazuki Nakamura*, Hiroyuki Wakabayashi**, Hisashi Shinsho***, Hideo Maeno*, Seiho Uratsuka*,
Akitsugu Nadai*, Toshihiko Umehara*, and Toshifumi Moriyama*
* Communications Research Laboratory
** Japan Aerospace Exploration Agency
*** Kushiro International Wetland Centre
* 4-2-1 Nukui-kita, Koganei-shi, Tokyo, 184-8795 Japan
E-mail kazun@crl.go.jp

1. Introduction

The wetland is mostly distributed in the moist low temperature area at high latitudes. The wetland has the peat bog, which forms the accumulation of undecomposed plants. The important thing to notice is that the peat bog is similar to the aerial part of biomass in accumulating carbon. Since the amount of carbon cannot be ignored in the wetland, there is an urgent need to monitor the wetland ecosystem. The knowledge of the wetland metamorphosis obtained by observing the wetland forest change.

We chose Kushiro wetland in Hokkaido as the test site. Since Synthetic Aperture Radar (SAR) can observe continuously in any weather conditions, it is useful for observing the high humidity area such as the wetland. This paper describes some results applying multi parameter SAR data (multi-frequency, -polarization and -incidence angle) to monitor the wetland forest.

2. Test site

We chose Kushiro wetland as the test site for monitoring the wetland by using SAR. The vegetation of Kushiro wetland is almost the same as the wetland at high latitudes [1]. The ground truth acquisition sites were placed on the right side shore of Kushiro River. There were 7 points in total, the northern sites were N1 to N3 and the southern sites were S1 to S4. The purpose of setting the northern and the southern sites was to confirm the backscatter from the wetland forest with the different ground surface condition. The ground surface under the forest is as follows: the northern sites were flooded and the southern sites are covered with the peat bog. The ground truth data acquisition sites are shown in Fig. 1.

3. Data acquisition

3.1 SAR data

Communications Research Laboratory (CRL) and Japan Aerospace Exploration Agency (JAXA) developed an airborne X- and L-band SAR system in their joint project, and it is called Pi-SAR (Polarimetric and interferometric-SAR). It is installed on the airborne, Gulfstream II. Resolution in both azimuth and range directions are 1.5 m for the X-band and 3.0 m for the L-band. Both SARs can make fully polarimetric observations. The X-band and the L-band data of Pi-SAR were acquired during 3 flight paths in the east to west direction, with the incidence angle changing to 23°, 36° and 47° at the scene center on 9th May 2003. Each one of the analysis scenes has footprints of 5 km by 5 km. In order to compare the SAR data with the ground truth data, Pi-SAR data were given processes of smoothing, using moving average filter with the window size of 5 by 5, a collection to backscattering coefficient and a map projection.

ISBN: 4-88552-207-2 C3055©IEICE

3.2 Ground truth data

The ground truth was acquired in synchronous with Pi-SAR observation. It is considered that the backscatter depends only on the wetland forest, unaffected by grass because grass does not exist in May. The basic structural parameters related to the biomass are thought to be the height and the diameter at breast height (DBH) of the tree. Alder is the dominant species of the wetland forest. Therefore, the ground truth data was obtained to focus on these parameters. In order to measure its parameters, the observation area was set to be 5 m by 5 m at each site. The measurement results of the height and the DBH at each site are shown in Fig. 2. This figure was derived from the height and the DBH on all sites. Averages of measurements were 4.0 m to 7.3 m and 4.2 cm to 9.6 cm respectively.

4. Data analysis

We investigated the relation between the ground truth data and the backscattering coefficient. The backscattering coefficient increases as the height or the DBH increased for all frequencies and incidence angles. The incidence angle characteristic and the polarization characteristic were seen from the relation. As an example, the relation between the height and the L-band backscattering coefficient at test sites is shown in Fig. 3.

Moreover, we found that the backscattering coefficient of HH polarization was stronger than the backscattering coefficient of VV polarization in the northern sites (flooded surface). But, the backscattering coefficient of VV polarization was stronger than the backscattering coefficient of HH polarization in the southern sites (peat bog surface). This suggestes the possibility of classifying the ground surface conditions under the wetland forest by using both backscattering coefficients of HH and VV polarization. Because L-band has high transmmisivity to the forest canopy, its backscatter caused by branches can be negligible. Therefore, we proceed the discussion in this paper by using the L-band data.

5. Backscattering model for wetland forest

5.1 Characteristics of model

The backscattering model for wetland forest was considered as following features: (1) The interaction of three layers of air/alder/ground surface is assumed; (2) The layer of the alder canopy decides the dielectric constant in changing the volume density; (3) The microwave propagation considers only the first order scattering; (4) The branches of the wetland forest are negligible in the L-band observation because the microwave can penetrate; (5) In case the ground surface is flooded, the backscatter is dealt with secular reflection that does not consider the contribution of its roughness. In case the ground surface is peat bog, the backscatter from the peat bog is considered; the surface scattering is caused by its roughness.

5.2 Backscattering model

In forestless area, an incident microwave reaches the ground surface. On the other hand, in forest area, the backscatter is generated by scattering from the forest canopy. The flooded surface or the peat bog surface have upward scattering that are dominated by surface scattering. Therefore, the backscattering mechanism was considered for the microwave propagation and focused attention on the interaction between the canopy of the wetland forest and its boundary. Scattering paths in the developed model is illustrated in Fig. 4.

Here, the backscattering coefficient σ^0 from the wetland forest can be written as [2]

$$\sigma^0 = 4\pi\cos\theta\frac{I^s}{I^i} = 4\pi\cos\theta(1-\Gamma_0)\left\{\frac{2\Gamma_s\Gamma_b}{L^2} + \Gamma_d + \Gamma_g\right\} \qquad (1)$$

where θ is incidence and scattering angle, I^s and I^i are scattering and incident power density, respectively, Γ_0, Γ_d, Γ_g, $\Gamma_s\Gamma_b$ are power reflectivity coefficients of the scattering from the boundary of air/canopy, the direct scattering of alder, the direct ground surface scattering (in case of the peat bog), and the double bounce scattering caused by an interaction of alder/ground surface, respectively, and L is the one way power loss coefficient.

5.3 Calculation procedure and result

The scattering from the wetland forest was calculated by the sum of the first order scattering incoherent of the reflectivity coefficient in air/canopy boundary, the volume extinction coefficient of the canopy and the scattering cross section of the alder. The average dielectric constant of the canopy was calculated by using Two Phase Mixture Model [3]. Then, the canopy was assumed to be composed of air and the alder. The volume extinction coefficient is the sum of the volume absorption coefficient and the volume scattering coefficient that were calculated by the average dielectric constant of the canopy and the scattering cross section of the alder, respectively. The scattering cross section of the alder was modeled with a finite length dielectric cylinder [4]. In case of the peat bog surface, its backscattering component was calculated by using Integral Equation Method Model (IEM) [5]. The double bounce scattering caused by the interaction of alder/ground surface was calculated by multiplying the bistatic scattering component of the alder and the ground surface.

As an example, the calculation result by assuming the maximum biomass of the alder in test site is shown in Fig. 5. We could see that the backscattering coefficient of HH polarization is stronger than the backscattering coefficient of VV polarization in the flooded surface, and the scattering path is dominated by the double bounce scattering of alder/ground surface. But the backscattering coefficient of VV polarization is stronger than the backscattering coefficient of HH polarization in the peat bog surface, and the scattering path is dominated by the direct scattering from the ground surface. This calculation results agree well with the observation results.

6. Conclusion

Kushiro wetland in Hokkaido was chosen as the test site of the wetland forest observation by using Pi-SAR. We carried out the ground truth observation and experiment in synchronous with Pi-SAR data acquisition when grass did not exist in May 2003. The relation between the height or the DBH and the backscattering coefficient in test sites could indicate that the backscattering coefficient increases as the height and the DBH increased for all frequencies and incidence angles. Moreover, we found that the backscattering coefficient of an excess polarization is different when the surface condition is different. Then, the simple backscattering model for wetland forest was developed and applied to derive the backscattering coefficient in different biomass and ground surface conditions. This model could explain the scattering mechanism that is related to biomass of the wetland forest and the ground surface condition under it.

References

[1] H. Oguma and Y. Yamagata, "Study on Effective Observing Season Selection to Procedure the Wetland Vegetation Map," Jpn. Soc. photogramm. Remote Sens., vol.36, No.4, pp.5-16, 1997.

[2] K. Nakamura, J. Miura, H. Wakabayashi, H. Shinsho and F. Nishio, "Study on Biomass Observation in Kushiro Wetland by using Multi-Incidence Angle SAR data," J. Remote Sens. Soc. Jpn., vol.22, no.2, pp.135-148, 2002.

[3] G. P. de Loor, "Dielectric properties of heterogeneous mixtures containing water," J. Microwave Power, vol.3, pp.67-73, 1956.

[4] G. T. Ruck, D. E. Barrick, W. D. Styart and C. K. Krickbaum, "Radar Cross Section Handbook," vol.1, Plenum Press, New York, 1970.

[5] A. K. Fung, Z. Li and K. S. Chen, " Backscattering from a randomly rough dielectric surface," IEEE trans. Geosci. Remote Sens., vol.30, pp.356-369, 1992.

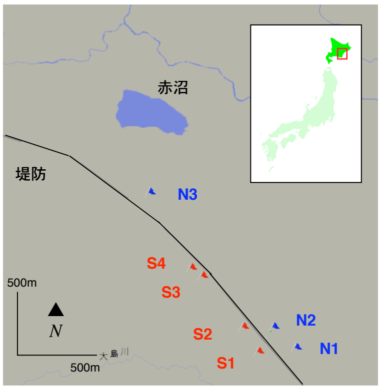

Fig. 1 Ground truth data sampling sites in Kushiro wetland. (Northern sites are 3 pts, Southern sites are 4 pts)

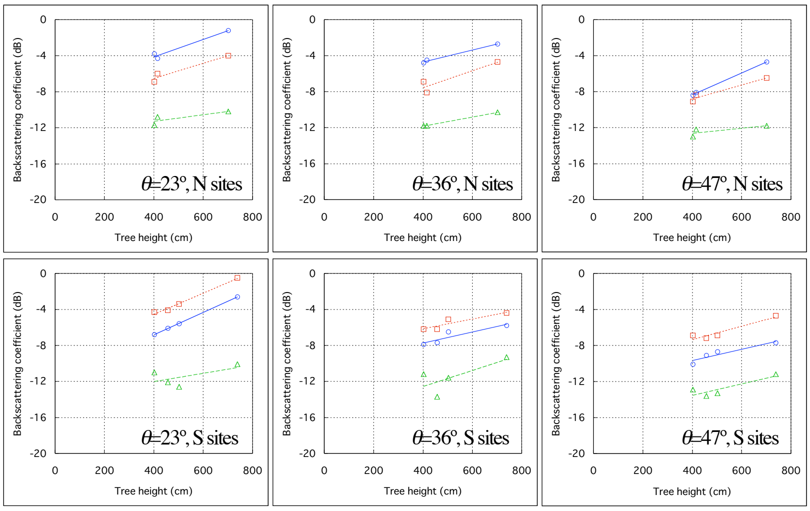

Fig. 3 Relation between alder height and L-band backscattering coefficient.

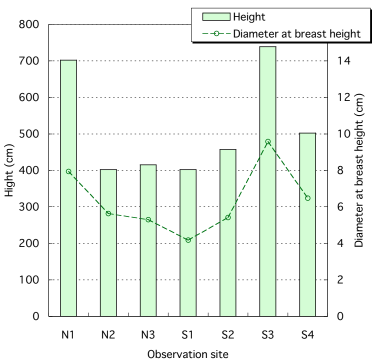

Fig. 2 Results of ground truth data acquisition of tree height of wetland forest and diameter of breaset height.

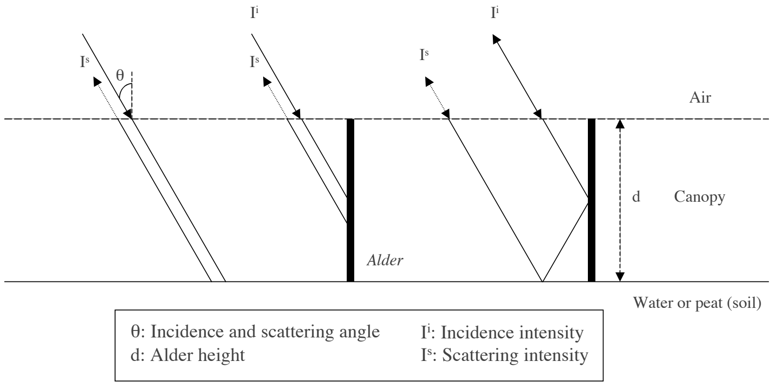

Fig. 4 Schematic diagram of scattering paths considered in the developed model.

(a) Direct scattering from ground surface.

(b) Direct scattering from alder (wetland forest).

(c) Double bounce scattering caused by interaction of alder and ground surface.

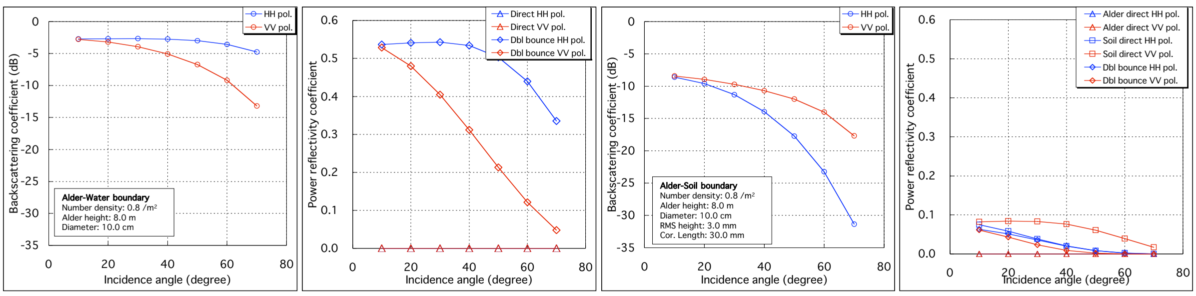

Fig. 5 Calculation results using the developed scattering model for wetland forest.

(a), (c) Relation between incidence angle and backscattering coefficient of HH and VV polarization.

(a) Flooded surface. (c) Peat bog surface.

(b), (d) Relation between incidence angle and power reflectivity coefficient at different scattering path.

(b) Flooded surface. (d) Peat bog surface.