J-1.1.2 Study on the Estimation of Vegetation Characteristics with an Airborne Synthetic Aperture Radar

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Abstract -- A method to estimate biomass in forest has become a subject of special interest because the importance of forests in the Earth's carbon cycle has been increasingly recognized. We study a method to estimate a biomass with airborne synthetic aperture radar (SAR). Our airborne SAR provides dual-frequency (L- and X- bands), full polarimetric data with a high resolution of 1.5 m. Our test site is Tomakomai (42.43'N, 141.34'E), which is located in the northern part of Japan. The survey on the biophysical properties were conducted at the same period of flight experiment in July 1999. We describe the discrimination between spieces using polarimetric or multi-temporal SAR data. Moreover we report the relation between biophysical properties and backscattering coefficient of SAR.

1.INTRODUCTION

The forest monitoring has become a subject of special interest because the importance of forests in the Earth's carbon cycle has been increasingly recognized. Multifrequency and polarimetric Synthetic Aperture radar is effective tool for retrieving the biophysical properties of forests and detecting the deforestation. Several studies on forest monitoring with multifrequency and polarimetric SAR were conducted for large uniform areas of forest [1]-[5]. An accumulation of knowledge on the forest monitoring with various SAR on various forest types is necessary in order to develop algorisms of estimating biophysical properties of forests and to decide optimum SAR parameters for forest monitoring. For these propose we have observed forests in Tomakomai (42.43'N, 141.34'E) with an airborne polarimetric and interferometric SAR (Pi-SAR). Pi-SAR has been developed by CRL and NASDA and conducted flight experiments since 1996 [6]. We also measured the biophysical properties (diameter, height, basal area and leaf area index) at the same time of flight experiments on July 1999. We deal with the dependence of backscattering coefficiet on frequency, polarimetry and speces. We investigate the relation between biophysical properties and backscattering coefficient of SAR. We also discuss the seasonal change of the forests using Pi- SAR data on February, July, and October.

2.RESEARCH OBJECTIVE

Our final goal is to obtain the relation between a backscattering coefficient and biophysical properties. To achieve this goal we need to clasify forest by species because a backscattering of different spieces behave in different manner. Furthermore we study the seasonal change. Therfore our study was conducted from four points of views as follows.

(1) Forest monitoring with a high resolution SAR image.

(2) The discrimination between species by polarimetry and multi-frequency.

(3) The character of the seasonal change.

(4) The relation between a backscattering coefficient and biophysical properties.

3.METHODOLOGY

The flight experiments in Tomakomai with Pi-SAR were conducted on October 1998, February, July and October 1999. We have observed from almost same flight parameters in each experiment. Information of each flight is listed in Table 1 and sensor parameter is given in Table 2. The Pi-SAR imagery on July 1999 is shown in Fig. 1 for L- and X- bands as three-polarization (HH, HV, VV) false-color composites. A summary of the Pi-SAR imaging parameters is given in Table 3.

Tomakomai site (42.43'N, 141.34'E) is located in the northern part of Japan and level land. The forests consist of natural areas covered with deciduous trees and afforested areas of coniferous trees. The forest of the size of about 10km x 5 km is spread between lake Shikotsu and Tomakomai town. Trees have been planted by small units. The maximum uniform unit is at most 500 m x 100 m. The main planting species are a kind of larch (Larix leptolepis Gordon), a kind of fir (Abies mayriana M. et K) and two kinds of spruce (Picea jezoensis Carr. and Picea glehnii Mast.).

We deployed six trehidoral corner reflectors of the size with 0.8 m leg length on July and October 1999. Three of them were put in the clear cut region and the others in forest. The transmitted microwave of L-band from Pi-SAR was received under trees for studying the amount of penetration on October 1999. Biometric surveys at the Tomakomai site was conducted in July 1999. The biophysical properties (diameter, height, basal area and leaf area index) were measured at the 26 sampling locations. The sampling locations were designed on the straight line and the flight course of Pi-SAR were parallel to the line of sampling locations. The average diameters were distributed between 15 and 40 cm. The soil moisture and ground roughness were measured on July 1999.

The multi-temporal composite image for HH polarization is shown in Fig. 2. Red, Green and Blue are allocated to each image on July 99, October 98 and February 99. The scene of Fig. 2 is the same as Fig. 1. To composite SAR images of different season, ground control

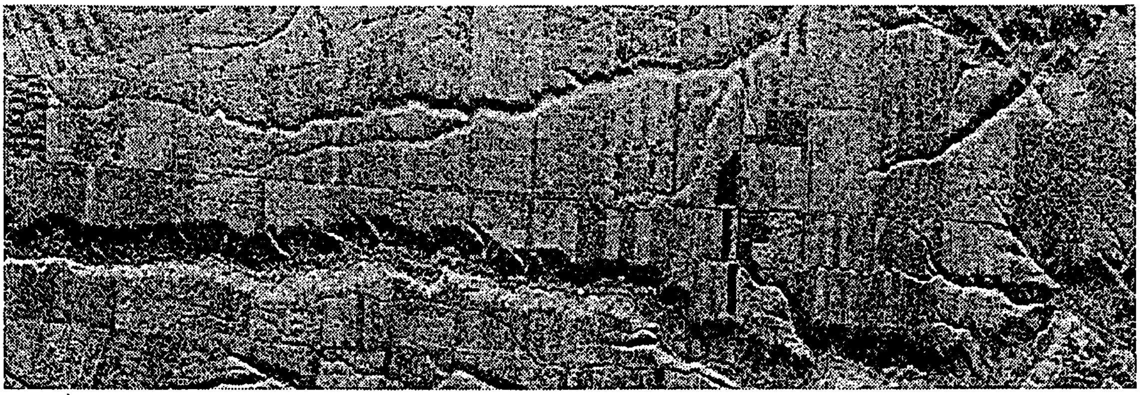

Figure.1 (a) The L-band polarimetric composite image on Jul99 (R: HH, G: HV, B: VV)

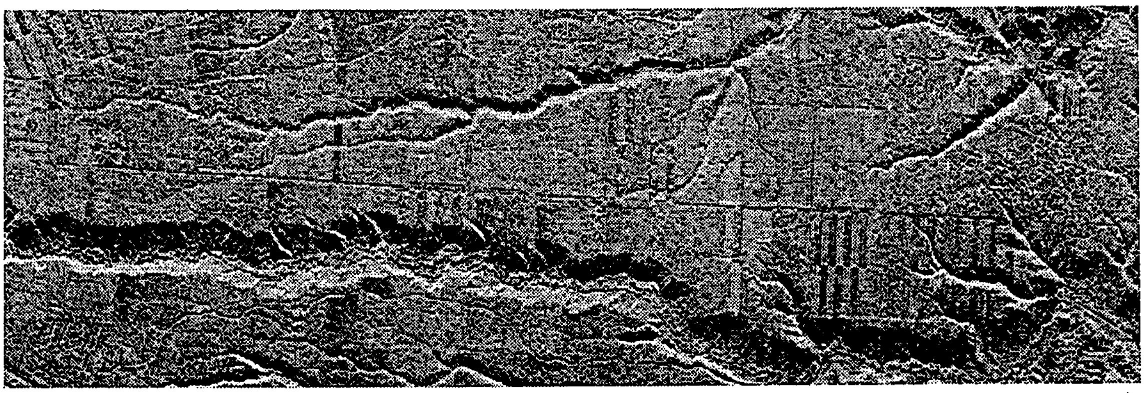

Figure.1 (b) The X-band polarimetric composite image on Jul99 (R: HH, G: HV, B: VV)

Figure.2 (a) The multi-temporal composite image for LHH.(R: Jul99, G:Oct98, B: Feb99)

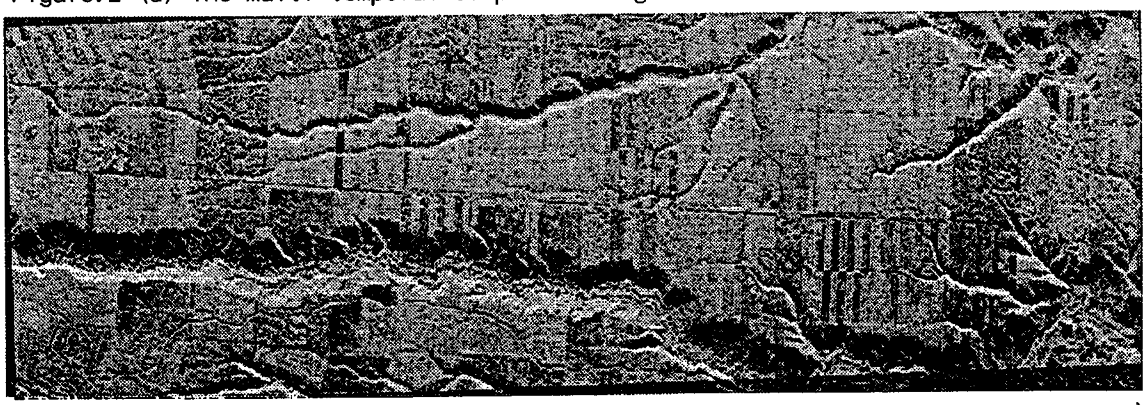

Figure.2 (b) The multi-temporal composite image for XHH.(R: Jul99, G:Oct98, B: Feb99) points from image were used.

Table 1. Information of observation

Date	10/26/98	02/24/99	07/14/99	10/14/99
Altitude(m)	11922	11753	12599	12203
Speed (m/s)	170	173	221	179
Drift angle (degrees)	0.56	4.21	5.05	7.94
Weather Temperature (Celsius)	Fine Leaf-on	Fine Leaf-off 2.3 snow was 30cm deep	heavy rain Leaf-on 18.7	Fine Leaf-on 15.8

Table 2. Sensor parameter

Band	L	X
Frequency (GHz)	1.27	9.55
Wavelength (cm)	23.6	3.14
Polarizations	full polarimetry	
Pulse bandwidth (MHz)	50	100
Pixcel spacing (m)	2.5	1.25
Resolution Az/Rg (m)*	3.0/6.1	1.5/3.0

** The range resolution is at the incidence angle of 40 degreer after grond projection.*

Table 3. Image parameter

Image Parameters	(4 looks, Ground range)	
Image center(Lat,Lon)	42deg.44'05"N,141deg.31'25"E	
Look angle(near-far)	34.6 – 42.8	
Image size (km)	9 (Az) x 3 (Rg)	
Pixcel spacing (m)	2.5 (L)	1.25 (X)

4.RESULT

(1) Forest monitoring with a high resolution SAR image.

Many open land in forest, a logging road and the shape of streams are identified in Fig.1 and Fig.2. Many ground control points without any filtering to reduce the speckle noise are available to registarate images.

(2) The discrimination between species by polarimetry and multi-frequency.

There are eight typical regions with different color in Fig. 2(b). By comparing these regions with the map for management of forest produced by a regional forestry office, three species have good correspondence. Each region of a kind of larch (Larix leptolepis Gordon), a kind of fir (Abies mayriana M. et K) and a kind of spruce (Picea glehnii Mast.) corresponds to light blue, dark brown and light brown in Fig.2 (b). The backscattering coefficient of these three species for each season is shown in Fig. 3. The change of X-band backscattering among three species is large, while the change of L-band is small. The backscattering coefficients of these species by each polarization are shown in Fig.4. The change of backscattering coefficients of x-band and HH polarization is 3dB, while the changes of others is less than 1.5 dB. Nevertheless it is possible to discriminate these three species in the x-band polarimetric composite image of Fig.1 (b). Moreover the spruce region is identified as white region in L-band polarimetric composite image.

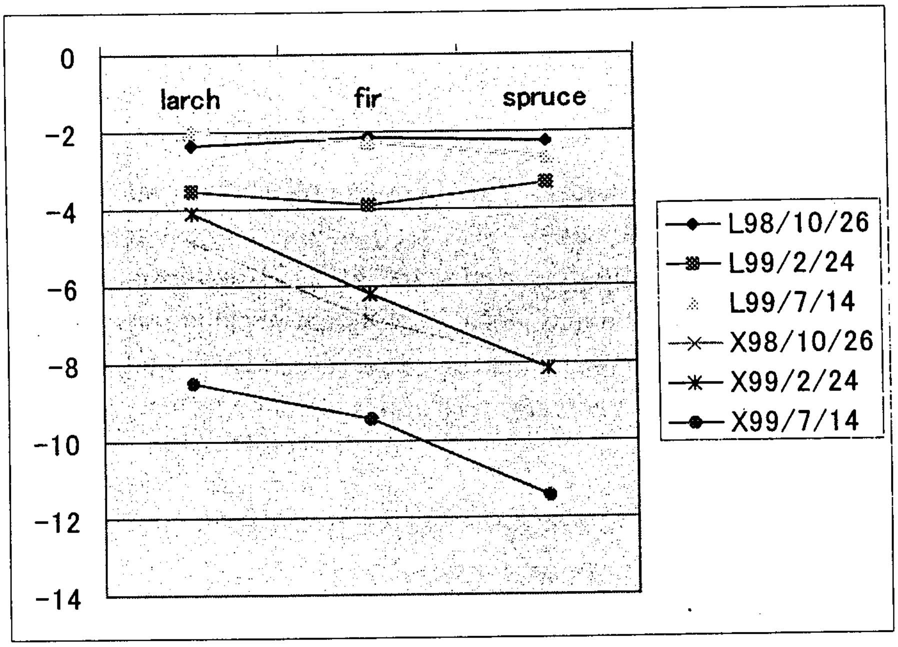

Fig. 3. The backscattering coefficient of HH polarization for three typical species observed in three seasons (October 1998, February 1999 and July 1999)

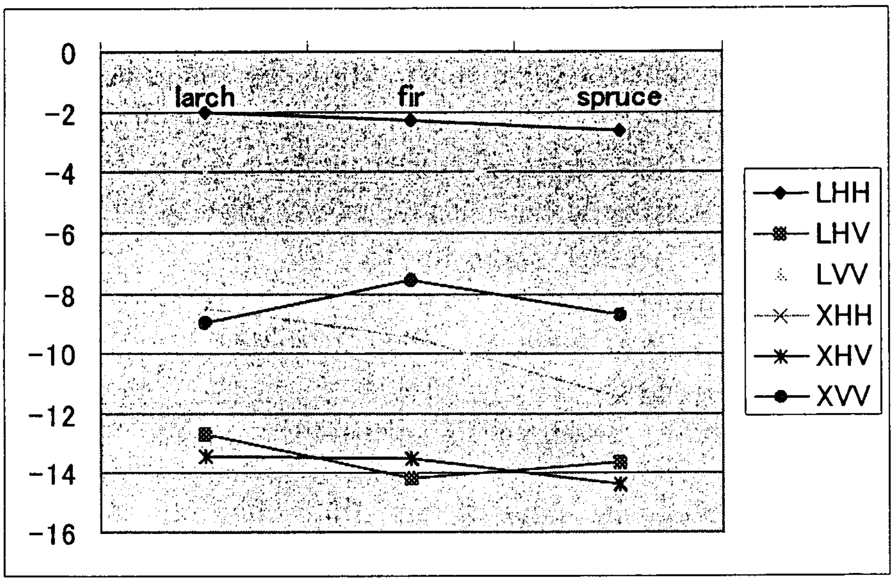

Fig. 4. The backscattering coefficient of each polarization for three typical species observed in July 1999

(3) The seasonal change.
The temporal backscattering coefficients for eight typical regions selected as different color regions in Fig. 2(b) are shown in .Fig.5 and Fig. 6. The region of 4,5,and 6 corresponds to a larch, a spruce and a fir. The backscattering of L-band and HH-polarization for the typical regions except resion of L7 is minimum at the observation on February. But the backscattering of X-band and HH-polarization for the typical regions except region of X5 and X8 is maximum at the observation on February. The both regon of X5 and X8 belong to the region of spruce (Picea glehnii Mast).

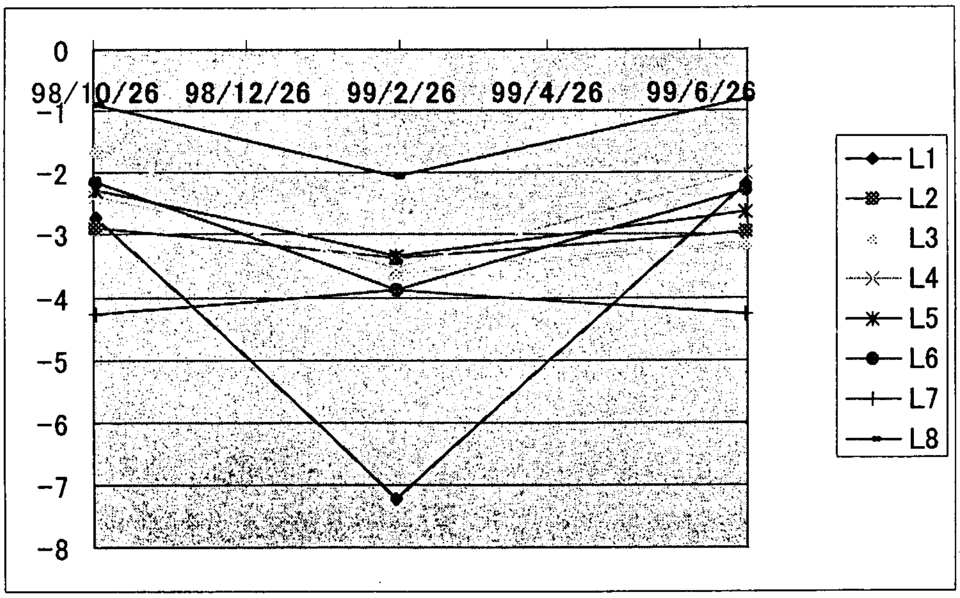

Fig. 5. The seasonal change of L-band HH backscattering coefficient for typical regions.

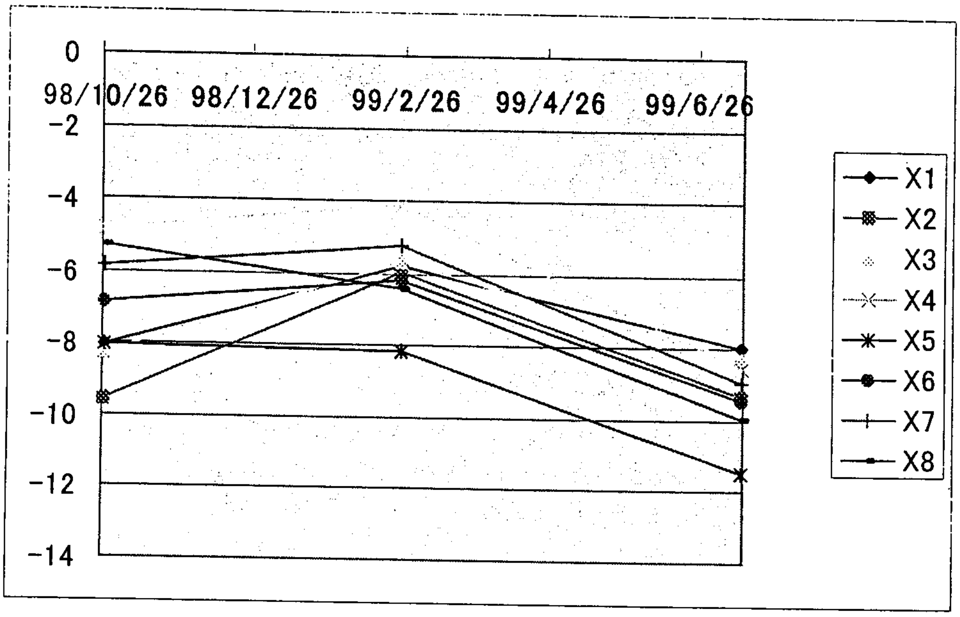

Fig. 6. The seasonal change of X-band HH backscattering coefficient for typical regions.

(4) The relation between a backscattering coefficient and biophysical properties.
At first each position of biophysical surbey on SAR image were decided. Next the backscattering coefficients were averaged over the three radius of 15m, 22.5m and 30 m respectively. The backscattering coeffcients were transferred into dB unit. Finally the correlation coefficients between backscattering coefficients and biophysical properties (diameter at breast height (DBH), height, basal area and leaf area index (LAI)) were caliculated. The results of correlation coefficients are listed in Table 4.

Table 4 Correlation coefficients between biophysical properties and backscattering coefficients (for the radius of the average region of 15, 22.5 and 30 m)

R=15m	LHH	LHV	LVV	XHH	XHV	XVV
DBH	0.4748	0.6305	0.7861	-0.2995	-0.0856	-0.2975
Height	0.5227	0.3904	0.5953	-0.4033	-0.0665	-0.3744
LAI2000	-0.0707	0.2203	-0.0967	0.3276	0.5860	0.1227
Basal area	0.1435	0.2112	0.7202	0.2687	0.1198	0.1892

R=22.5m	LHH	LHV	LVV	XHH	XHV	XVV
DBH	0.4215	0.8079	0.7475	-0.3894	-0.1011	-0.3547
Height	0.5425	0.5719	0.6190	-0.3917	0.0608	-0.3523
LAI2000	-0.3517	0.2563	0.1730	-0.2818	0.6284	0.2054
Basal area	-0.2355	-0.0288	0.4205	-0.2602	0.1881	0.2216

R=30m	LHH	LHV	LVV	XHH	XHV	XVV
DBH	0.5715	0.9206	0.8277	-0.5369	-0.2293	-0.5458
Height	0.6194	0.7264	0.8347	-0.4330	0.0060	-0.4622
LAI2000	-0.1518	0.2696	0.2314	-0.0114	0.3064	-0.0274
Basal area	-0.1216	0.1484	0.3825	0.0233	0.0931	0.0537

The backscattering coefficient on L band VV and HV polarization data has good correrations with the diameter at breast height and tree hight. Furthermore the relation between the total volume per ha and the backscattering coefficient for a species (picea glehnii mast) is shown in Fig.7. The volume is defined as the product of basal area and tree height. The DBH of these samples are distributed between 10.8 and 23.3 cm.

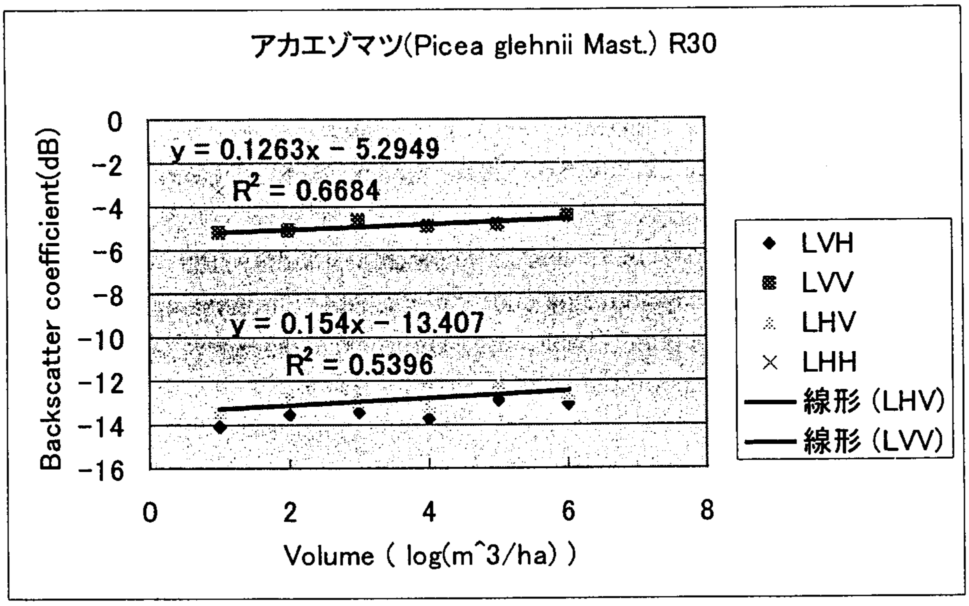

Fig. 7. The relation between volume and backscattering coefficient for piece glehnii mast.

(5) Radar interferometry by single path

A cross-track radar interferometry provide the height information by using the phase difference of the signals received by two antennas. The X-band interferometric image of Tomakomai is show in Fig.8. The size of the image is 5 by 5 km. The fringes coresspond to the change of topographic height. The shape of streams are identified well. The cross strips on image coresspond to the difference of the tree height.

5.SUMMARY

We have observed forests in Tomakomai (42.43'N, 141.34'E) with an airborne dual-frequency and polarimetric SAR for two years. The discrimination between three kind of spieces using polarimetric or multi-temporal SAR data was conducted. Moreover the backscattering coefficient on L band VV and HV polarization data has good correrations with the diameter at breast height and tree hight. Furthermore the relation between the total volume per ha and the backscattering coefficient for a species (picea glehnii mast) was obtained.

Fig.8 The phase difference image in Tomakomai

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