DEPENDENCY OF BACKSCATTERING FROM OCEAN SURFACE ON WIND DIRECTION BY USING AIRBORNE SAR -- LOW WIND SPEED CASE --

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1. INTRODUCTION

To analyze the coastal environment, the ocean surface wind field with high spatial resolution is one of important factors. The spatial resolution of the spaceborne SAR is enough fine to utilize to this purpose. However, the spaceborne SARs have been designed to operate in single channel. As a result, one component of the wind parameters must be determined externally to estimate the ocean surface winds using the single channel SAR. The coarse spatial resolution of these external data worsens the spatial resolution of the estimated wind field and leads the error of the wind measurement. In recent years, many spaceborne polarimetric SARs have observed the earth surface including the ocean. However, the polarimetric feature of backscattering from the ocean surface is not well known enough to utilize the ocean wind measurement, especially in the L- and X-bands.

The dependencies of backscattering from ocean surface in the L-band X-bands under relatively strong wind as 13m/s were analyzed by using airborne SAR [1]. In this paper, the dependencies of NRCS and of the polarization ratio on the wind direction under relatively weak wind as 5m/s are analyzed.

2. OBSERVATION AND SAR PROCESSING

The National Institute of Information and Communications Technology (NICT) and the Japan Aerospace Exploration Agency (JAXA) has been developed an airborne dual-frequency polarimetric SAR in the L- and X-bands, called the Pi-SAR [2]. The airborne SAR is able to shorten the time interval between observations of same area as less than several ten-minutes. The high-spatial resolution of the Pi-SAR provides enough number of data for the multi-look processing in short azimuth distance. As a result, the Pi-SAR is able to observe the same and small area of ocean with different illumination azimuths in enough short time to ignore the spatial and temporal change of the wind field.

In this paper, two Pi-SAR data under almost same wind speed were analyzed. Each Pi-SAR data were obtained with three illumination azimuths. The one observation was done on the southeastern sea off the Uchiura

Bay in Hokkaido, Japan between 02:49 to 03:17 (UT) on Jun 13 2002. The wind measured at the weather stations on the coast around the target area ware about 3 to 5m/s from ESE within the observation. The precise wind direction is estimated as 115 degree due north using the wind slicks on the intensity images. Another observation was done around the Aguni Island on western sea off the Okinawa main Island, Japan between 02:33 and 03:34 (UT) on November 6 2004. The wind measured at the weather station on the Aguni Island was 4m/s from NE. The precise wind direction is estimated as 27 degrees based on the extension of the shadow area behind the island. Because the three observations in each observation event were done in less than an hour, the wind condition is assumed as constant during each observation event, hereinafter. The processing areas are selected in up-wind region of land. The extents of processing area are much larger than the spatial scales of many ocean phenomena.

To reduce the influence of ocean surface phenomena, the measured NRCS is averaged at each ground-range bin. Then the NRCS in the incidence angle is calculated from the bin averaged NRCS by re-sampling using the Gaussian filter with the e-folding scale of 1 degree. Hereinafter, the paper deals only the parallel components of both radar frequencies.

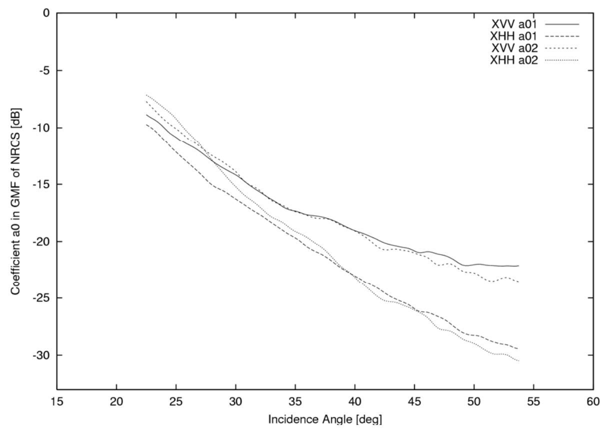
3. ANALYSIS OF DEPENDENCY TO WIND DIRECTION

3.1. Geophysical Model Function

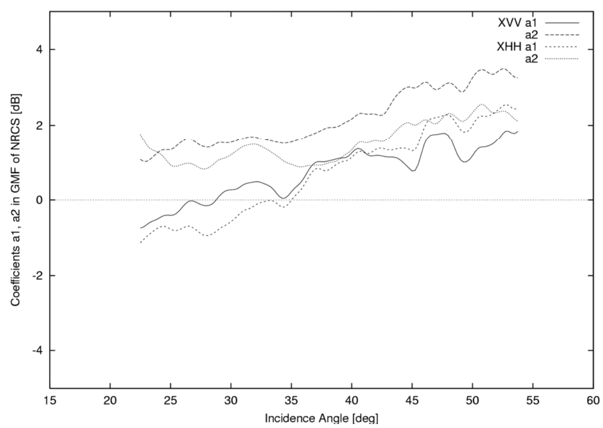
The dependency of measured values on ocean winds is modeled as a function of the ocean wind parameters with other observation parameters. The geophysical model function (GMF) of the measured value σ in dB scale on the relative wind direction φ is described as

$$\sigma_m = a_0 + a_1 \cos\phi + a_2 \cos 2\phi .$$

Moreover, all coefficients are also the function of the wind speed and the incidence angle. The coefficient a_0 is the independent coefficient to wind direction. The asymmetric dependency coefficient a_0 and symmetric dependency coefficient a_2 represent the contrasts between up- and down-wind conditions and between the parallel- and cross-wind conditions, reprehensively. Because the profiles of the independent coefficients of both observations agree well, the wind speed at both observations are assumed as same. Moreover, the dependency of the measured value on the wind direction is also assumed as same. Under these assumptions, the common dependency coefficients a_1 and a_2 between two observations and the independent coefficients a_{0j} (j = 0: off Uchiura Obs., 1: Aguni Obs.) for each observation are estimated.

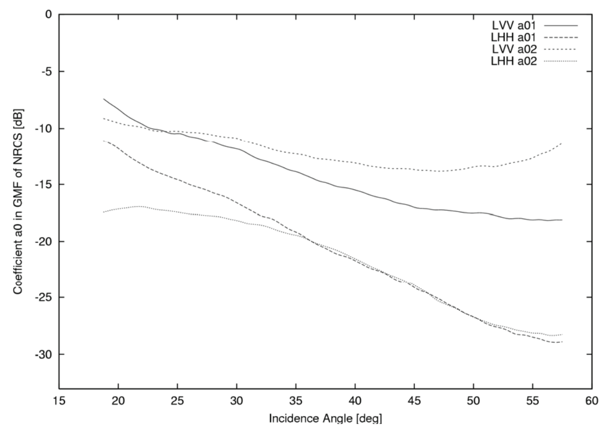


(a) GMF coefficients a_{0j}

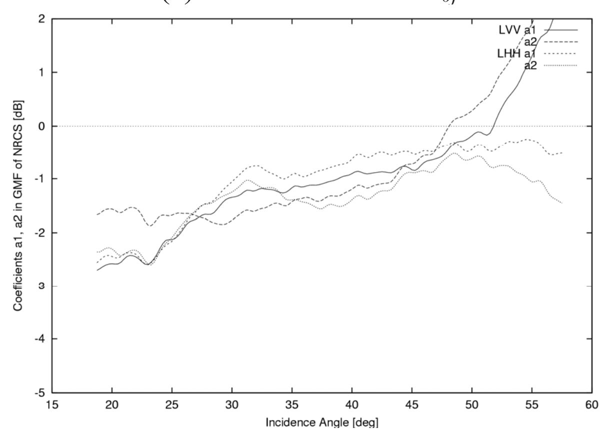


(b) GMF coefficients a_1 and a_2

Fig. 1: GMF coefficients of NRCS in the X-band.



(a) GMF coefficient a_{0j}



(b) GMF coefficients a_1 and a_2

Fig. 2: GMF coefficients of NRCS in the L-band.

3.2. Normalized Radar Cross Section

Figures 1 and 2 represent the GMF coefficients of the NRCS in the X- and L-band parallel polarizations, respectively. The independent coefficients a_{0j} for the X-band parallel polarizations agree well between both observations. The independent coefficients in the X-band HH polarizations more rapidly decrease than that in the X-band VV polarizations.

In the X-band parallel polarizations, the contributions of the symmetric dependency coefficients are greater than those of the asymmetric dependency coefficient. Though the symmetric dependency coefficient in X-band VV polarization is larger than that in the X-band HH polarization, the asymmetric dependency coefficients are almost same between the parallel polarizations. Moreover, the asymmetric dependency coefficients in both parallel polarizations change the sign at around 35 degree of incidence angle. The change of signature means the intensity relation between the up- and down-wind conditions changes at the incidence angle of 35 degrees.

In the L-band, there are large differences of the independent coefficients of the NRCS GMF in each parallel polarization between two observations. In the HH polarization, though the independent coefficients are almost same in the incidence angle region larger than 35 degrees, there are large difference between them in the incidence angle region smaller than 35 degrees. Moreover, in the VV polarization, the independent coefficients differ in whole range of the incidence angle. The cause of these differences of the independent coefficients is unknown. The influence of the external noise or some failures in the installation of the radar may cause these differences. Because the dependency on the wind direction is calculated from the NRCS differences between the different illumination azimuths, the influence of the installation failures may be cancelled out between them. The directional external noise may cause the error on the analysis of the dependency on the wind direction.

There are not so large differences between each dependency coefficient in the L-band parallel polarizations. The asymmetric dependency coefficients in both parallel polarizations become negative. The negative value of the asymmetric dependency coefficients of the NRCS GMF means that the NRCS under the cross-wind condition is greater than that under the parallel-wind conditions. On the other hand, the analysis under the relatively strong wind conditions as 13m/s, the NRCS under the parallel-wind condition is greater than that under the cross-wind condition, as same as in the X-band [1]. However, such strange relation of the NRCS in the L-band was also pointed out by Isoguchi and Shimada [3]. As a result, there may be some unknown backscattering mechanism intensify the NRCS under the cross-wind condition.

4. CONCLUDING REMARKS

As a result of this study, the dependencies of the NRCS in the X-band on the wind direction represent different features between the parallel polarizations. The difference of dependencies of the NRCS on the relative wind direction suggests the possibility of the wind measurement using an X-band polarimetric SAR. Moreover the difference of the dependency between the radar frequencies also suggests the ocean wind measurements by a dual-frequency SAR

5. REFERENCES

[1] A. Nadai, T. Umehara, T. Matsuoka, T. Kobayashi, and S. Uratsuka, "Dependency of backscattering from ocean surface on ocean winds observed by an airborne SAR," IEICE Tech. Rep., SANE2008-80, Nov. 2008.

[2] T. Kobayashi, T. Umehara, M. Satake, A. Nadai, S. Uratsuka, T. Manabe, H. Masuko, M. Shimada, H. Shinohara, H. Tozuka, and M. Miyawaki, "Airborne dual-frequency polarimetric and interferometric SAR," IEICE Trans. Commun., vol. E83-B, no. 9, pp. 1945-1954, Sep. 2000.

[3] O. Isoguchi and M. Shimada, "An L-band ocean geophysical model function derived from PALSAR," IEEE Trans. on Geoscience and Remote Sensing, vol. 47, no. 9, pp. 1925-1936, Jul. 2009.

[4] D. R. Thompson, T. M. Elfouhaily, and B. Chapman, "Polarization ratio for microwave backscattering from the ocean surface at low to moderate incidence angles," Proc. IGARSS, Seattle, WA, 1998.

[5] T. M. Elfouhaily, "Modele couple vent/vagues et son application a la teledetection par micro-onde de la surface de la mer," Ph. D. thesis (in English), Univ. Paris VII, Paris, France, 1996.