Estimation of Polarization Ratio for Sea Surface Wind Retrieval from SIR-C SAR Data

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Abstract: Wind speeds have long been estimated from C-band VV-polarized SAR data by using the CMOD algorithms such as CMOD4, CMOD5, and CMOD_IFR2. Some SAR data with HH-polarization without any observations in VV-polarization mode should be converted to VV-polarized value in order to use the previous algorithms based on VV-polarized observation. To satisfy the necessity of polarization ratio (PR) for the conversion, we retrieved the conversion parameter from full-polarized SIR-C SAR image off the east coast of Korea. The polarization ratio for SIR-C SAR data was estimated to 0.47. To assess the accuracy of the polarization ratio coefficient, pseudo VV-polarized normalized radar cross section (NRCS) values were calculated and compared with the original VV-polarized ones. As a result, the estimated pseudo values showed a good agreement with the original VV-polarized data with a root mean square error by 0.99 dB. We applied the pseudo NRCS to the estimation of wind speeds based on the CMOD wind models. Comparison of the retrieved wind field with the ECMWF and NCEP/NCAR reanalysis wind data showed relatively small rms errors of 1.88 and 1.91 m/s, respectively. SIR-C HH-polarized SAR wind retrievals met the requirement of the scatterometer winds in overall. However, the polarization ratio coefficient revealed dependence on NRCS value, wind speed, and incident angle.

Key Words: Sea Surface Wind, SAR, SIR-C, Polarization Ratio, CMOD

1. Introduction

Wind vector measurements from space have provided us with an opportunity to understand oceanographic phenomena and their scientific processes. Wind fields over ocean have been obtained from scatterometer since early 1990’s. The scatterometer winds have contributed to a variety of researches and applications, especially for climate changes and environmental changes. However, its low spatial resolution of about 25 km limits its applicability, especially at coastal regions. Accordingly, it makes difficulty to observe small-scale phenomena related to local air-sea interaction.

Synthetic Aperture Radar (SAR) is capable of high-resolution imaging, so that the detailed distribution of wind vectors, which is hard to be obtained from scatterometers, can be retrieved even
for the coastal regions. In addition, it offers a capacity of all-weather imaging for the ocean surface irrespective of atmospheric condition, except for extreme events related to heavy rainfall. These unique imaging availabilities of SAR make it possible to observe various oceanic features such as waves (Beal et al., 1986; Dobson and Vachon, 1994; Kim, 1999), currents (Lyzenga and Marmorino, 1998; Romeiser et al., 2002; Kang and Lee, 2007), internal waves (Gasparovic et al., 1988; da Silva et al., 1997) and near-coastal and finer-scale wind fields to investigate the spatial variability of wind field (Kerbaol et al., 1998; Vandemark et al., 1998; Lehner et al., 2000; Friedman et al., 2001; Kim, 2009). SAR-derived wind fields are now being used in various applications such as coastal environment monitoring (Korsbakken et al., 1997; Choisnard et al., 2003; Moon et al., 2010), assimilation of ocean circulation models (Young et al., 2000; Kawamura et al., 2002; Zabeline et al., 2011), and mapping global wind power (Furevik and Espedal, 2002; Hasager et al., 2004; Christiansen et al., 2006).

Most of SAR winds have been retrieved from C-band data with three major wind retrieval algorithms; CMOD4 (Stoffelen and Anderson, 1997), CMOD_IFR2 (IFREMER-CERSAT, 1999), and CMOD5 (Hersbach et al., 2007). Unfortunately, all of the C-band algorithms were developed using VV-polarized observations. Several C-band SAR satellites, such as RADARSAT-1, ENVISAT, and SIR-C, carried HH-polarized SAR without any observations from VV-polarization. The models for the VV-polarization have limited the diverse utilization of SAR imagery with other frequencies and polarization states in the estimation of wind speeds. For the further understanding of spatial and temporal variation of detailed wind distributions, we need lots of wind data to acquire a sequence of wind fields from many accessible SAR data as possible. For the extensive utilization of the data, we need a certain model for HH-polarized data.

Since there is no robust wind retrieval model for C-band HH-polarization SAR data, the previous studies have suggested a hybrid wind retrieval method combined with polarization ratio, which is defined as HH-polarized normalized radar cross section (NRCS) over VV-polarized NRCS (HH / VV), to utilize C-band SAR data imaged at HH-polarization. This approach has attempted to convert NRCS values of HH-polarized SAR to VV NRCS values by applying the polarization ratio. Wind vectors were then derived using C-band geophysical model functions (GMFs) such as CMOD algorithms that have been validated for decades (Vachon and Dobson, 2000; Horstmann et al., 2001; Monaldo et al., 2002; Kim and Moon, 2002). The results of the hybrid wind retrieval approaches have enhanced the applicability of the polarization ratio models for HH-polarized SAR data such as RADARSAT-1 and ENVISAT ASAR imagery. The rms (root mean square) errors of wind speeds retrieved from the method were by 1.38 to 1.99 m/s, which satisfied the requirement of satellite scatterometry (Monaldo et al., 2004; Feng et al., 2004; Signell et al., 2010). For more accurate retrievals, several studies have suggested some of polarization ratio coefficients optimized for RADARSAT-1 and ENVISAT ASAR.

Spaceborne Imaging Radar C-band/X-band Synthetic Aperture Radar (SIR-C/X-SAR) operated at C-, L-, and X-bands with sensor characteristics of fully polarization (HH, HV, VH, and VV). It has a capability of providing multi-frequency and multi-polarization SAR data which could be observed simultaneously and thus appropriate for the inter-comparisons between the different frequencies and polarization states. However, none of the previous researches has attempted to propose the coefficient for HH-polarized SIR-C SAR data.