Retrieval of Spherical Ocean Wave Parameters Using RADARSAT-2 SAR Sensor Observed at Chukk, Micronesia

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Abstract : The purpose of this study is to estimate the spherical wave parameters that appears in synthetic aperture radar (SAR) image acquired over the coast of Chukk, Micronesia. The retrieval of ocean wave parameters consists of two main stages: the first is to determine the dominant wavelengths by Fast Fourier Transform (FFT) over 16 sub-image areas and the second is to estimate wave slopes and heights using dispersion relationship under various water wave conditions. It is assumed that the spherical waves are linear and progressive. These type of waves have the range and azimuth components traveling in radial directions. The azimuth travelling waves are more affected by the velocity bunching mechanism and it is difficult to estimate the wave parameters for these affected areas in SAR imagery. In order to compensate these effects, the velocity bunching ratio (VBR) based on modulation transfer function (MTF) was compared with the intensity ratio for neighbor area in the radial direction in order to assign the spherical wave properties for azimuthally travelling waves. Dispersion relation provides the good estimates for the wave heights for all the selected sub-image areas in the range of 1m to 2m. VBR based on MTF was found to be 0.78 at wave height of 1.36m, while the intensity-based VBR was 0.69 which corresponds to the height of 1.75m. It can be said that the velocity bunching accounts for azimuthally travelling spherical waves and the difference results from the sea-bottom effects.

Key Words : Spherical waves, Wave parameters, FFT, SAR–ocean imaging, Dispersion relation, Velocity bunching.

1. Introduction

SAR images have provided the potential contribution for measuring the various oceanic phenomena such as estimation of the wavelengths, directions, as well as wave heights under several metrological conditions. Over an ocean, SAR image consists of fine resolution with some rough signatures of oceanographic phenomenon such as waves, currents and internal waves (Vachon and Raney, 1991; Kim, 2009).

The linear system approaches to the SAR imaging mechanism (Alpers, 1983) that provides a basis for a
procedure to estimate wave height spectra from SAR intensity images. The effectiveness of a linear system approach to SAR wave imaging can be explored through numerical simulation study. These simulations begin with the input ocean spectrum in order to estimate height topography, use of models based on the backscattered signals are as the function of wave height which includes the mapping of intensity levels depending on wind blow over the sea surface.

Retrieval of the ocean wave parameters by SAR depends on sea state. In addition, it also depends on SAR imaging mechanisms such as velocity bunching, tilt and hydrodynamic modulations. The normalized radar cross section (NRCS) for the case of flat sea surface shows negative value of more than −10 dBs (Hasselmann and Hasselmann, 1991; Hasselmann et al., 1996). An analytic expression for the non-linear ocean-to-SAR spectral transform (Krogstad, 1992) is exists which describes the SAR image spectrum as a function of ocean wave fields. It shows the relation for ocean wave spectrum derived from SAR signal spectrum. SAR image spectrum was also obtained through the modulation transfer function (MTF) which produces accurate estimates of slope- and height-variance spectra (Frank and David, 1986).

There are numerous models have been proposed in order to retrieve the wave parameters either in deep or in coastal sea waters using various analytical expressions. Polarimetric analysis (Ouchi and Yang, 2010; Shirato and Ouchi, 2010) is also one way to estimate wave heights with the use of polarimetric ratio of radar cross section for HH- and VV-polarization images for the purpose to estimate the wave slopes by means of pixel based analysis. Co-polarization (HH/VV) image data are less affected by wind and sea states and they shows better response for wave parameter estimation as compared to the cross-polarization (HV/VH) image data (Vachon et al., 1994).

Poor SAR images with low SNR (signal-to-noise ratio) are extremely difficult to analyze and obtain the wave parameters. The selection of sample size ($M \times N$ pixels) of SAR images is the important but critical task. Computation time shows increased value for the big size datasets (Kuo et al., 1999). Sea surface backscattering (Valenzuela, 1978) response senses by sensors are more dominantly affected by surface scattering phenomenon between the interactions of electromagnetic and sea surface waves.

In this paper we will introduce the simple technique to correlate SAR-derived wavelengths using Fast Fourier Transform (FFT) with the implementation of the dispersion relation to investigate wave slopes and Analysis is to be carried out over 16 sub-image areas extracted from SAR image spherical waves observed by SAR near to the coast of Chukk Island, Micronesia. Apart from the previously developed models, this method proposes the correlation between the SAR image properties with the wave hydrodynamics.

2. Experimental data and method

1) Experimental data

The ocean wave measurement is carried out by means of satellite based RADARSAT-2 SAR sensor which operates in C-band (5.4 GHz) of the electromagnetic spectrum. SAR signals are more affected due to variation in metrological conditions such as sea state, wind speed, and direction etc. Higher the wind speed rougher will be the sea surfaces; in particular, rough signatures will be appeared in SAR image due to signal smearing effect.

Fig. 1 shows the Fine quad-polarization (HH, HV, VH and VV) data acquired on November 4, 2010 at 19:40:21.60 UTC in descending orbit pass, and are mapped with ground control points (GCP) for the