THE RELATIONSHIP BETWEEN RADAR BACKSCATTER CROSS SECTION AND OCEAN WAVE PARAMETERS AT LOW INCIDENCE ANGLES

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1. INTRODUCTION

The ocean wave plays an important role in studying marine meteorology and physical oceanography, developing marine resources and building coastal engineering. Ocean wave spectrum can completely describe ocean wave on linear theory. Up to now, the only radar system implemented on spacecraft for measuring ocean wave spectrum is the synthetic aperture radar (SAR), which views the sea at medium incidence angle (20º-60º). But SAR has some drawbacks because of the lack of power and azimuth wave number cutoff.

Spaceborne radar system for measuring ocean wave spectrum at small incidence angle should have some advantages over those at the middle angles [1]. A quasi-specular scattering model is often used to describe the radar cross section at near nadir incidence [2]. The two key parameters in the simple model are the nadir reflection coefficient and a quantity related to the mean square slope of the sea surface. However, owing to a lack of radar observation data at small incidence angles, it had been impossible to investigate the relationship between the radar backscatter and ocean wave parameters in details.

The successful operation of the Tropical Rainfall Mapping Mission (TRMM) has provided a unique, long-term, extensive dataset of accurate normalized radar backscatter cross-section (NRCS, denoted $\sigma°$) measured from the Ku-band Precipitation Radar (PR). Tran et al. [3] discussed the effect of long waves on this radar backscatter. The present study uses rain-free radar observations from PR and wave parameters measured from buoys to investigate the relationship between significant wave heights (SWH), wave age, wave direction, wind speed, wind direction and PR $\sigma°$. Fully empirical model functions relating PR $\sigma°$ to SWH in terms of incidence angle under different sea states are firstly derived from collocated buoys and PR measurements.

2. DATASETS

The PR operates at 13.8 GHz, horizontal polarization and the near-nadir incidence angle ranging from 0.1º to 18º [4]. The data product used herein is TRMM PR standard product 2A21 from the Goddard Distributed Active Archive Center. It contains information on ocean surface radar backscatter cross section, total path attenuation, and the presence of rain in the measurement cell, as well as standard quality flags and navigation and instrument geometry (e.g. incidence angle) information [4]. Eight years of data set (2001-2008) with PR surface cross-section measurements obtained under no-rain conditions are used for this study.

The buoy data are obtained from the National Data Buoy Center (NDBC). The criteria used for the collocation between buoy measurements and PR observations are given as follows: time separation within 30 minutes and latitude and longitude separation less than 0.1º.

3. METHOD AND RESULTS

Firstly, we analyze the trend of $\sigma°$ toward SWH and relative wave directions (Figure 1, 2). The relative wave direction is defined as: $\varphi_{wave} - \varphi_{radar}$, where φ_{wave} is the main wave direction and φ_{radar} is Ku-band PR look direction, both with respect to the North reference. Figure 1 shows that $\sigma°$ is greater and it is sensitive to wave height and incidence angles in near nadir angles (0º-8º) and light-to-moderate wave height conditions. So, it's quite

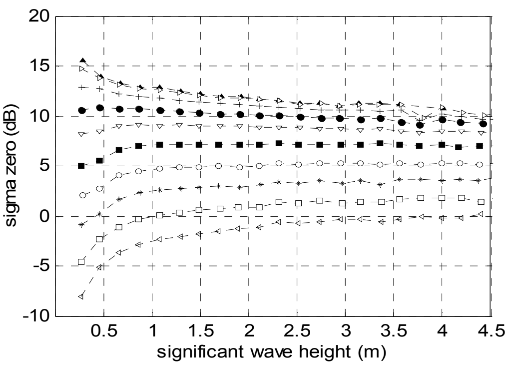

Figure 1. Ku-band PR radar cross-section as a function of significant wave height for different incidence angles (θ). From top to bottom: θ=0°,2°,4°,6°,8°,10°,12°,14°,16° and 18°.

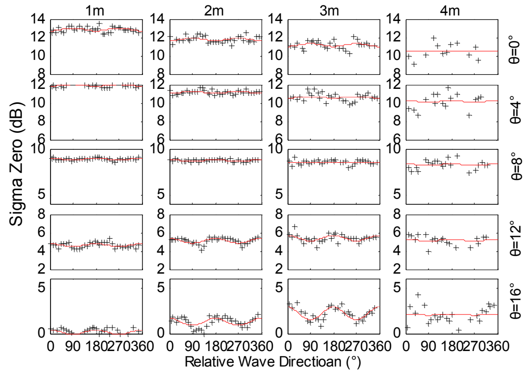

Figure 2. Variation of Ku-band PR radar cross-section with the relative wave direction for five different incidence angles from 0° to 16° and different SWH of 1 m interval. Overlaid is a cosine regression fit to better display the trend.

feasible to remote sensing light-to-moderate surface waves in those near nadir angles. But it seems the wave spreading information is not obvious at near nadir angles, especially when θ is less than 10° (Figure 2).

Secondly, sea waves are categorized into wind waves and swell. We analyze the quantitative relationship between SWH and PR σ° under swell conditions and the relationship between SWH, wave age and σ° in wind wave cases in each incidence angles bins.

Thirdly, wave direction observations from NDBC buoys are used to investigate whether or not the backscatter depends on relative wave direction in different sea wave conditions.

Based on the specular reflection theory of electromagnetic waves at rough sea surface, the wind wave spectrum model with a wave age factor [5, 6] and swell wave spectrum model with a SWH factor, the description of σ° in terms of incidence angle, significant wave height and wave age are also showed using the mean square slope, which is obtained by integration of the spectrums. The comparison with statistical model indicates that this analytical σ° with spectral approach is limited to certain sea states.

4. REFERENCES

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