SWELL INFLUENCE ON OCEAN SURFACE ROUGHNESS AND RADAR SCATTERING FROM THE OCEAN SURFACE

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Field measurements of ocean surface roughness spectrum indicate that swell exerts significant influence on short and intermediate scale waves (SISW) generated by local wind. As a result, the swell influence should reflect on the accuracy of wind velocity remote sensing relying on the relationship between wind speed and ocean surface roughness. In this presentation, the following will be discussed. (A) Observations of swell influence on the ocean surface roughness spectrum, including their wind speed dependence and swell modification of roughness components characterizing Bragg resonance and surface tilting in radar application. Several notable results include: (a) With increasing swell intensity, the spectral density increases in the long wave portion and decreases in the short wave portion of the intermediate scale waves. (b) There is a nodal point with respect to swell impact in the wave number dependence of the coefficient and exponent of the spectral parameterization function in the vicinity of wave number near 3 rad/m, suggesting that waves about a couple of meters long are insensitivity to swell influence. (c) Spectral density in the decimeter length scale becomes less sensitive to wind speed variation as swell intensity increases. (d) Increasing swell influence shifts wave breaking toward shorter and broader scales. (B) Computation of backscattering radar cross section (RCS) from the ocean surface using three spectral functions of the ocean surface roughness: Donelan-Banner-Plant (Plant 2002), Elfouhaily (1997), and Hwang (2008). Of the three wind wave spectral function, Hwang (2008) incorporates the swell effect through a swell index defining the relative spectral level between low and high frequency (with respect to reference frequency defined by wind speed and measured spectral peak frequency) spectral densities. Altogether, four spectral models [DU (D-spectrum with wind fluctuation of 1.5 m/s), E, H1 (windsea dominates) and H4 (swell dominates)] are generated. In addition to modification of surface roughness spectrum, ocean surface swell is also an importance source of tilting facets especially when the swell is steep (theoretical maximum inclusion angle of a limiting waveform is +/-30 degrees). Results to be presented include: (a) Comparison of the three roughness spectral models with available mean square slope measurements. (b) Comparison of RCS with several available field measurements at different radar frequencies, incident and azimuth angles as well as computations using CMOD4, SASS2 and Ku2001 model functions. (c) An attempt to quantify the swell effects on the RCS. Typically, with steep swell, the RCS is reduced and the data scatter is increased due to the enhanced tilting effects. (d) Discussions on pitfalls and issues encountered in the attempt to account for the broad range of length scales covering swell of several hundred meters to the Bragg resonant waves on the order of radar wavelength.

Fig. 1 shows an example of the mss comparison between remote sensing measurements and results integrated from the spectral models mentioned above. The DU spectrum yields very good agreement at low frequency but underpredicts the mss at higher frequencies. The E spectrum produces good agreement at both high and low ends of the frequency range and low wind speeds in the full frequency range but underpredicts the intermediate frequency condition. Overall, the H spectrum (with H1 and H4 forming approximate envelops of expected range of mss) seems to provide a better agreement with the collected data sets but the wind speed dependence at the low frequency range (C band) differs considerably from the data trend. Comparing the H1 and H4 curves, in the presence of swell (H4) the rate of mss increase with wind decreases considerably, as would be expected from the mixture of contributions from local wind generation and nonlocal swell sources.

Fig. 2. shows an example of radar cross section computation and comparison with field measurement of radar cross section at 1.2, 3.2, 5.3, 13.7 and 17.25 GHz over the Atlantic Ocean (Unal et al., 1991). The azimuthally averaged RCS is shown with VV in the upper and HH in the lower panels at three incident angles (20, 30 and 45°). The circle and square markers represent field data. Computations with model functions are shown with plus for CMOD4, cross for SASS2, and asterisk for Ku2001. The dashed-and-dotted, dotted, solid, and dashed lines show results using the DU, E, H1 and H4 spectra, respectively. As noticed by Plant (1992), the model predictions using DU and E spectra are generally somewhat below the data of Unal et al. but closer to the values obtained from the scatterometer model functions. The cross section computation using the H1 and H4 spectra generally improves the agreement with data.

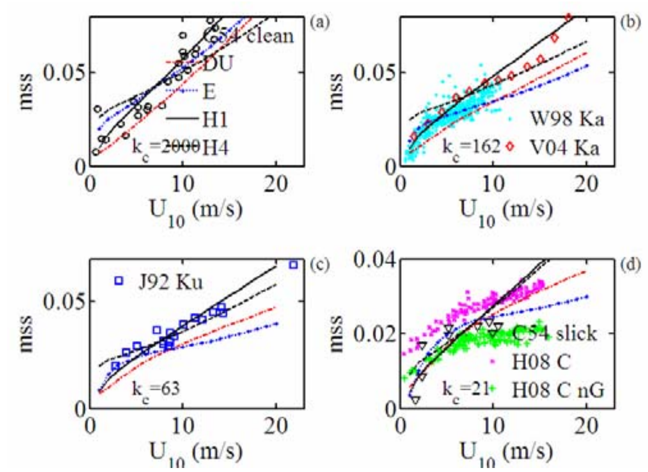

Fig. 1. Mean square slopes from integrating the spectra shown in Figure 1 from the spectral peak wave number to an upper cutoff wave number, k_c, and their comparison with field data: (a) k_c=2000 rad/m and the clean water sun glitter data, (b) k_c=162 rad/m and Ka band radar data, (c) k_c=63 rad/m and Ku band radar data, and (d) k_c=24 rad/m and slick water sun glitter data and C band radar data. Sources of data are given in Hwang (2008).

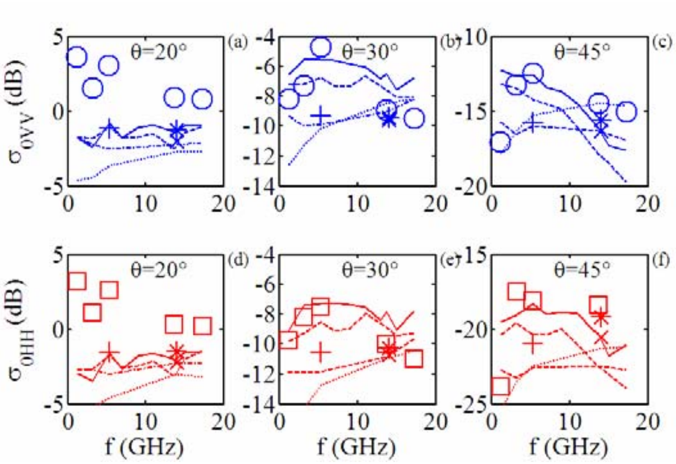

Fig. 2. Comparison of the calculated radar cross sections at 10 m/s wind (a, b, c for VV and c, d, e for HH at 20, 30 and 40° incident angle, respectively) at different radar frequencies and comparison with filed measurements (Unal et al. 1991). Symbols are: circle – measured VV, square – measured HH, plus – CMOD4, cross – SASS2, asterisk – Ku2001, dashed-and-dotted curve – DU spectrum, dotted curve – E spectrum, solid curve– H1 spectrum and dashed curve– H4 spectrum.

References

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