SPATIAL CHARACTERISTICS OF SHORT WIND WAVES IN THE OCEAN

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LONG-TERM GOAL

To study the surface roughness structure for: (1) understanding the influence on the backscatter of radars in remote sensing applications, and (2) applying the knowledge to the interpretation of wind, wave, and current parameters obtained from remote sensing techniques.

SCIENTIFIC OBJECTIVES

To investigate the effect of surface roughness structure on the altimeter backscattering return and quantify the improvement on wind speed derivation from radar cross section taking into consideration surface roughness properties.

APPROACH

Develop analytical expression of radar backscattering cross section taking into account modification of local incident angle due to surface tilting. Compare derivation with TOPEX altimeter and ocean buoy measurements in the Gulf of Mexico region. Gregg Jacobs and Bill Teague (NRL) extracted the TOPEX data, David Wang of Computer Science Corp. assembled the ocean buoy data for comparison.

WORK COMPLETED

Analytical expression derived, comparison with TOPEX and ocean buoy data accomplished. Results reported in meetings, technical reports, and journal papers.

RESULTS

It is found that the tilting effect of long waves produces an attenuation of the radar backscattering cross section. The calculated attenuation factor is in excellent agreement with TOPEX/POSEIDON (referred to as TOPEX for brevity) measurements. Two major contributors to the tilting mechanism are the wind generated waves with wavelengths much longer than the radar wavelength, and the ambient waves generated elsewhere and propagated into the measurement region. Using the information of the wavenumber spectra of short capillary-gravity waves measured in the ocean and an estimate of the ambient tilting wave components from the ocean, the calculated attenuation factor is in excellent agreement with TOPEX measurements. With the tilting effect accounted, the agreement improves significantly the wind speeds derived from the TOPEX Ku-band altimeter as compared to those from the collocated ocean buoys (see Figures 1 and 2).

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IMPACT/APPLICATION

The basis for relating radar measurements to wind speed is the realization that radar backscatter is caused by surface roughness. In the ocean, the surface roughness is mainly contributed by wind-generated surface waves. The measured radar intensity (the normalized radar cross section), s_0, however, was found to differ significantly from theoretical calculations using equations derived from scattering processes (e.g., Barrick, 1968) and measured physical properties of the surface roughness (e.g., Cox and Munk, 1954; Hwang et al., 1996). Most puzzling of all, calculations consistently indicated that the sea surface detected by radars, with wavelengths on the order of a few centimeters, was “rougher” than those detected by optical instruments that depend on light with wavelengths in the sub-micrometer wavelength range (Hwang, 1997). This perplexing result was not resolved in the past two decades since the advent of altimeter data. Up to this stage, the majority of wind speed algorithms are based on empirical or statistical analyses. The results obtained from this research show that our understanding of the scattering physics is fundamentally sound but the knowledge of the surface roughness is rather poor. The incorrect specification of the surface roughness led to inaccurate inference of the oceanographic parameters from remote sensing measurements.

TRANSITIONS

The research results have been reported in scientific meetings, technical reports, and journal papers.

RELATED PROJECTS

The knowledge and experience derived from this ONR sponsored program contribute to other ocean remote sensing programs using microwave radars (Trizna, sponsored by ONR and NRL) and data fusion projects that seek to assimilate atmospheric and oceanographic parameters from sources including remote sensing techniques (Perkins, sponsored by ONR and NRL). The results are also useful to the air-sea interaction community and the on-going development of passive microwave sensing of the environment such as the NPOESS program.

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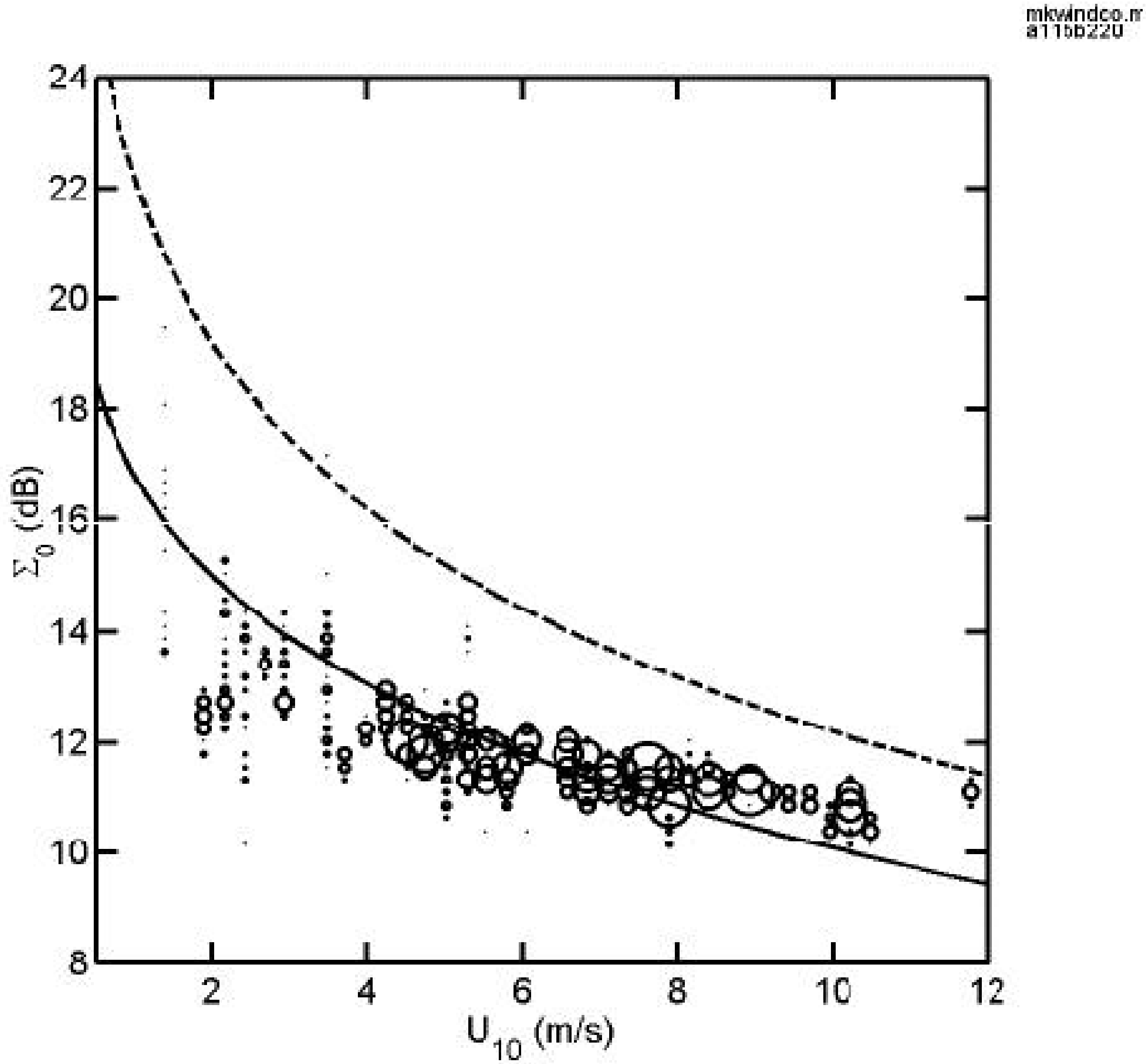

Figure 1. Tilting Effect on the Altimeter Backscattering Cross Section.

Circles: TOPEX Ku-band measurements; Dashed curve: without tilting consideration; Solid curve: With tilting effect. (Hwang, et al., 1997).

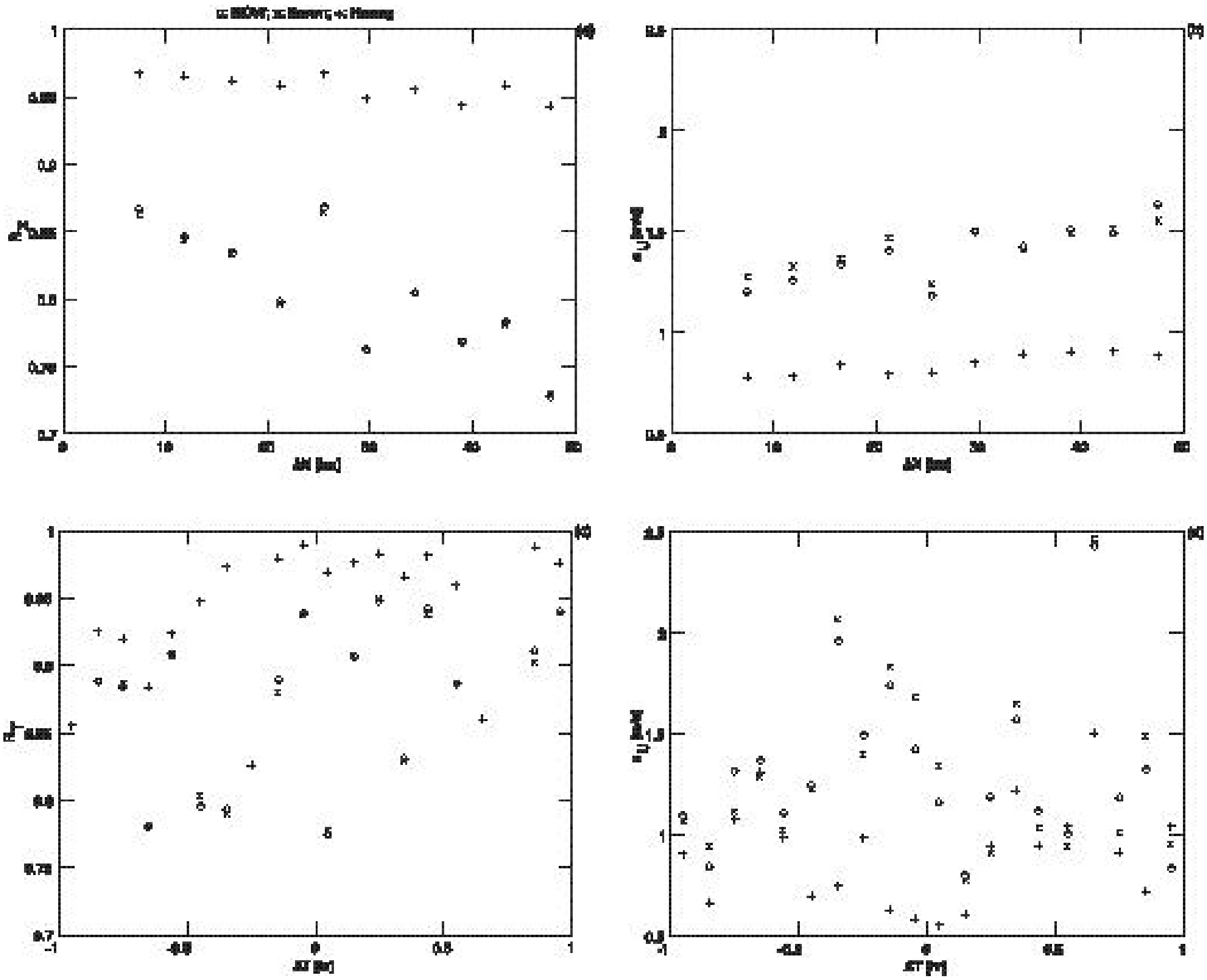

Figure 2. The Correlation Coefficient and RMS Difference of Wind Speed Measurements as Functions of Space Lags (a, b) and Time Lags (c, d).

Data set A115B220. x: B81 (Brown, et al., 1981), o: MCW (Witter and Chelton, 1991), +: Tilt-Surface. The improvement with consideration of tilting is significant (Hwang, et al. 1997).