ANALYSIS OF SURF ZONE RADAR BACKSCATTER MEASUREMENTS

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LONG-TERM GOAL

To understand the relationship between radar backscatter and wave breaking, especially in shallow water, and to develop remote sensing methods for measuring and monitoring processes related to wave breaking in littoral regions.

OBJECTIVES

The short-term objectives of this effort are to establish empirical or semi-empirical relationships between the radar backscatter and breaking wave parameters such as the wave height and energy dissipation rate, by comparing backscatter measurements made under a range of conditions with *in situ* wave measurements. Ultimately, a more fundamental understanding will be sought in terms of the hydrodynamic and electromagnetic interactions involved.

APPROACH

I have begun by examining the backscatter data collected by an airborne radar (the ERIM DCS) over the Field Research Facility at Duck, North Carolina, during a series of flights in May, 1996. I have also begun to examine radar data collected by the ERS satellite, access to which was granted by the European Space Agency in response to a proposal submitted as part of this effort. Finally, I plan to analyze marine navigational radar data collected by Dennis Trizna at Duck, NC, in order to investigate the backscatter at low grazing angles.

WORK COMPLETED

Data from two of the airborne synthetic aperture radar (SAR) images collected on May 7 and 14, 1996 have been analyzed and compared with wave measurements made at the Field Research Facility. Two ERS SAR frames of the Duck area have been acquired and one has been examined to date. I plan to order ERS images for some West Coast locations also, and have reviewed the wave data from several NOAA buoys on the days corresponding to the available ERS images in order to select an optimal data set for this analysis.

RESULTS

Two unexpected results were obtained during the first year of this project. The first is that the radar backscatter is not proportional to the rate of energy dissipation due to wave breaking, as was initially

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supposed. Rather, it was found that the radar cross section per unit area, integrated over the entire extent of the surf zone in the cross-shore direction, is proportional to the incident wave height or, roughly, the square root of the integrated energy dissipation rate. This result was obtained from an analysis of the two airborne SAR images shown in Figure 1. The incident wave height was approximately 1.5 m on May 7 and 0.5 m on May 14. The incident energy flux, and thus the rate of energy dissipation per unit distance in the along-shore direction, was therefore about a factor of nine larger on the first day than the second; but the integrated radar cross section is only about a factor of three larger.

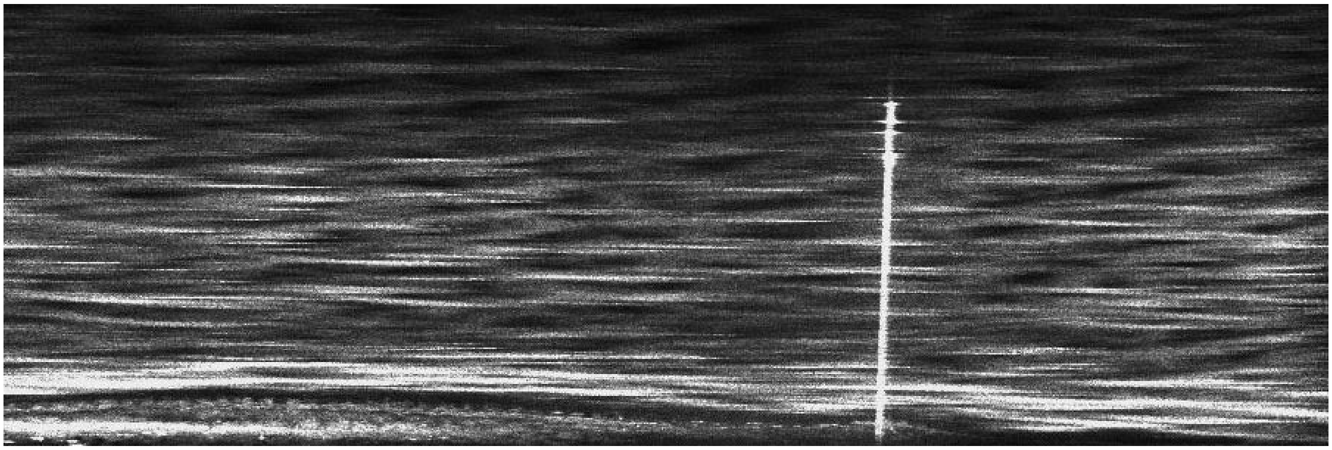


Figure 1(a). X-band, HH-polarization airborne SAR image collected over Duck, NC on May 7, 1996.

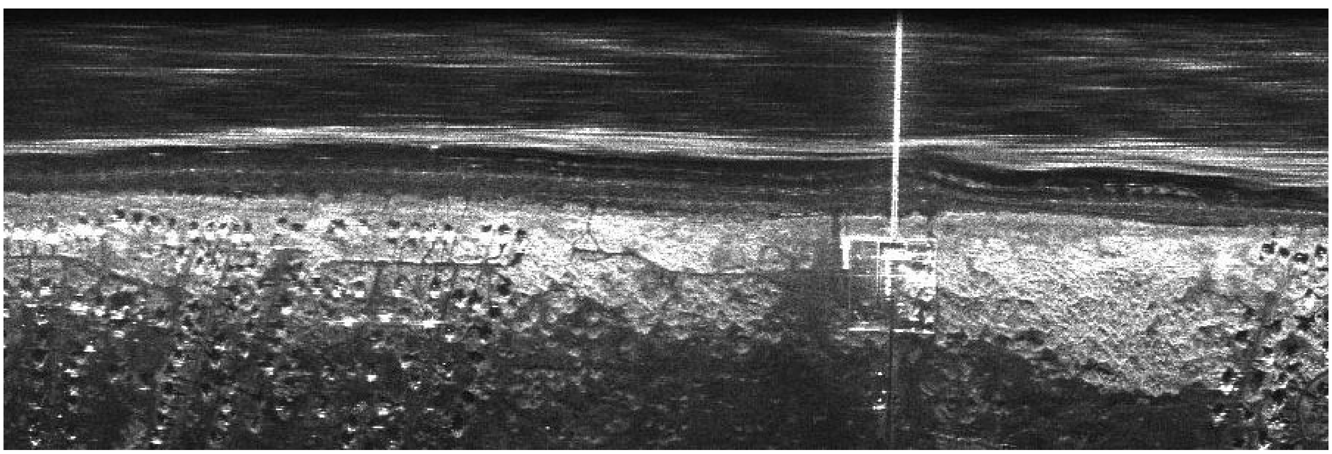


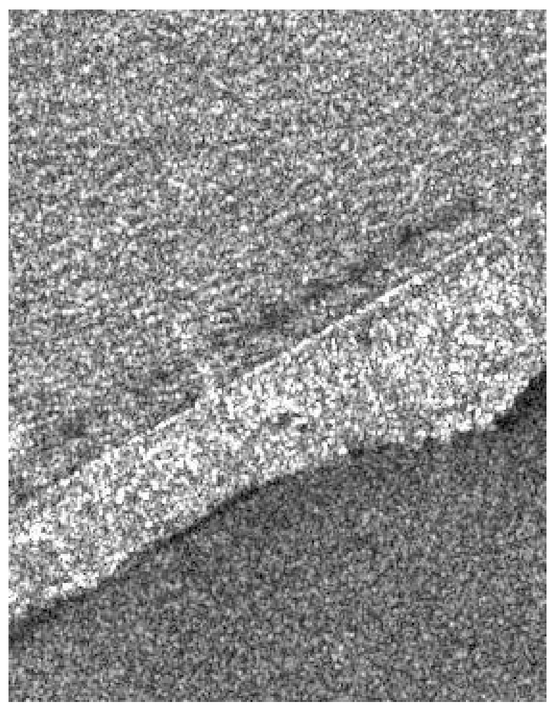
Figure 1(b). X-band, HH-polarization airborne SAR image collected over Duck, NC on May 14, 1996.

This result led to the development of a new model for the breaking wave backscatter, based on the assumption that the backscatter cross section is proportional to the surface area of the ‘breaking zone’ as defined by Duncan (1981) and as observed by Walker *et al.* (1996). According to this model the rate of energy dissipation per unit crest length is given by $\varepsilon \approx 0.1\rho g d_r L_r c \approx 0.01\rho g L_r^2 c$ where L_r is the length and d_r is the thickness of the breaking region or 'roller'. The radar cross section per unit crest length is then proportional to $L_r \approx 10\sqrt{\varepsilon / \rho g c}$, and the radar cross section per unit area is given by

$$\sigma^o \approx \sqrt{\frac{D f_B}{\rho g c \lambda}}$$

where $D = \varepsilon f_B / \lambda$ is the rate of energy dissipation per unit area, λ is the wave length and f_B is the breaking fraction.

The second result obtained during this investigation is that wave breaking in the surf zone can cause either an increase or a decrease in the radar backscatter, depending (apparently) on the wind speed as well as radar parameters such as the wavelength, polarization, and incidence angle. This is illustrated by the two ERS sub-images shown in Figure 2, both of which were collected on November 20, 1996, with an incident wave height of slightly over 1 m. The image on the left represents an area approximately 60 km north of the Duck pier, where the wind speed was apparently quite low (probably less than 3 m/s), as evidenced by the dark background in the offshore region. The bright band near the shoreline is interpreted to be the result of wave breaking in the surf zone, and is consistent with the bright returns observed in the aircraft images shown in Figure 1. The image shown in Figure 2(b) includes the region surrounding the Duck pier, where the wind speed was over 3.5 m/s according to measurements at the FRF facility. In this region, there is a dark band near the shoreline instead of a bright line. It is hypothesized that this dark band is due to a suppression of the short wind-generated waves that are responsible for the higher return in the offshore region.



(a) 60 km north of Duck, NC ***(b) near Duck pier (FRF facility)***

Figure 2. 3.5x4.5 km subsets of C-band, VV-pol ERS-2 image collected on November 20, 1996.

The decrease in backscatter near the shoreline in Figure 2(b) is related to the relative magnitudes of two effects that may depend also on the incidence angle and the radar wavelength. The incidence angle for the ERS images is 23^{o}, or about half that for the aircraft images in Figure 1, and the radar wavelength is roughly twice as large. These dependencies will be examined further through the analysis of additional data sets.

IMPACT/APPLICATION

The results of this ongoing investigation are expected to impact the development of remote sensing methods for monitoring coastal processes.

TRANSITIONS

Some results of this investigation have been used in the ONR Littoral Remote Sensing project.

RELATED PROJECTS

In addition to the aforementioned connections with the LRS project, this investigation is related to numerical electromagnetic scattering studies by Eric Ericson at ERIM International and to marine navigational radar observations by Dennis Trizna at NRL.

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