Dual-Polarized, Coherent Microwave Backscatter from Rough Water Surfaces at Low Grazing Angles

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In the absence of breaking waves, composite surface scattering theory explains backscatter from rough water surfaces well, enabling geophysical parameters such as wave heights to be extracted from microwave measurements (Plant and Keller, 1990; Plant, 2002; Plant et al., 2005). However, breaking can cause some geophysical parameters, such as currents, to be poorly measured by microwave systems. Unfortunately, it is often difficult to determine whether breaking is playing a significant role in the backscatter. The studies reported here investigate the conditions under which breaking is important in microwave remote sensing of the ocean.

We have made measurements of microwave backscatter from the ocean at low grazing angles from several ships in various geographic locations. Figure 1 shows our radars mounted on two different ships. We have compared normalized radar cross sections (NRCS) from these measurements with those from similar measurements made at higher grazing angles and with the predictions of composite surface scattering theory. We find that in the absence of surface disturbances such as current gradients, NRCS levels for VV polarization are rather well explained by composite surface theory at all grazing angles. However, measured NRCS levels for HH polarization are higher than theoretical predictions for grazing angles below about 45^o. This is in contrast to measurements on rivers at low wind speeds where composite surface theory seems to work well for both polarizations (Contreras and Plant, 2004). We also investigated the behavior of the maximum NRCS of internal wave surface signatures for both polarizations. Here values of the NRCS for HH polarization are significantly higher than those for undisturbed seas while VV NRCS values are changed to a much lesser extent. In fact, NRCS values at HH polarization and low grazing angles exceed those at VV by about 10 dB at the maximum of internal wave signatures (Figure 2).

Figure 1. Coherent, X-band radars mounted on the R/V Revelle (left) and the R/V Thompson (right).

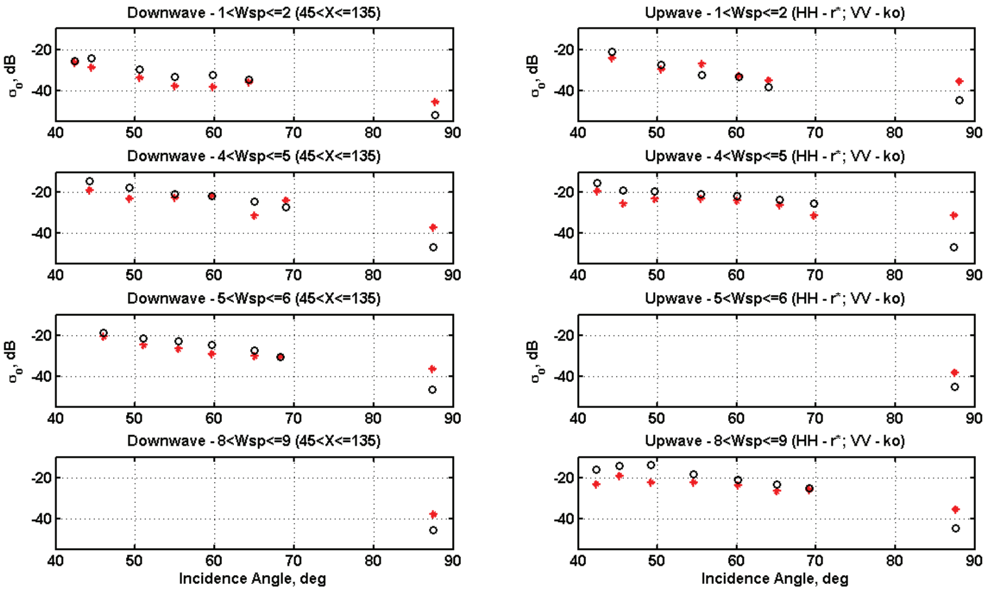

Figure 2. Maximum normalized radar cross sections induced by internal waves at various wind speeds. X is the angle between the antenna look direction and the direction from which the wind comes. Red is HH, black is VV.

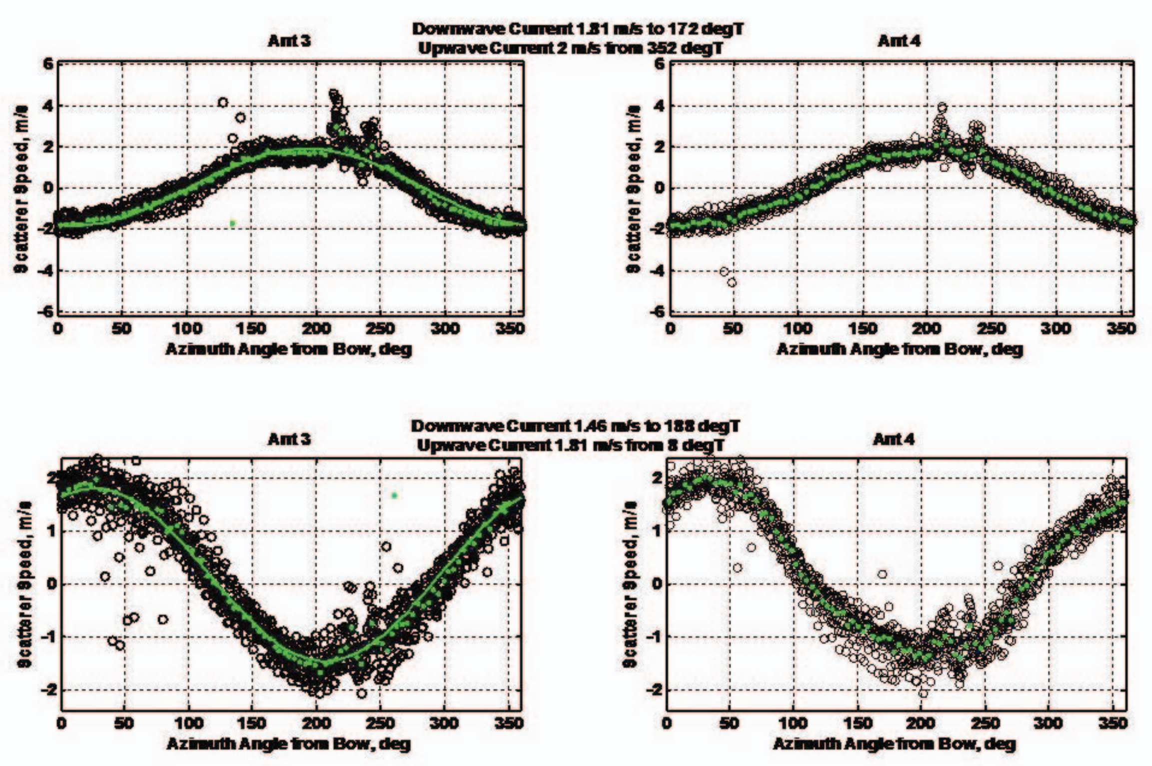

Figure 3. Angular variation of the first moment of the Doppler spectrum (converted to velocity) for two different antennas. Ship and Bragg speeds have been removed.

In the absence of surface disturbances, the dependence of the NRCS on azimuth angle is also very different for HH and VV polarizations at low grazing angles. For VV polarization, the NRCS behaves very similarly to its counterpart at higher grazing angles, exhibiting a second harmonic dependence on azimuth angle as is standard in scatterometry (Jones et al., 1977; Plant et al., 1998). For HH polarization, on the other hand, the NRCS maximizes when the antenna looks upwind and minimizes looking downwind, a first harmonic dependence.

These observations indicate that breaking waves strongly influence HH NRCS values at mid to low grazing angles while affecting VV values to a much lesser extent. In fact, it is tempting to infer that the sea surface must be disturbed by a current, as in the case of internal wave surface currents, in order for breaking waves to be manifest in VV backscatter. We believe that this is not the correct inference, however, based on measurements of the Doppler shifts observed at VV polarization at low grazing angles.

Such Doppler shifts, converted to velocity, are shown as a function of the azimuth angle relative to the ship's bow in Figure 3. Ship motion and Bragg wave speed have been removed. Ship superstructure blocks the antennas' view of the water between 200^o and 250^o. The top row corresponds to the ship heading in the direction of the wind and surface waves; the bottom row illustrates the change when the ship heads upwind. Note that apparent current when the antenna is looking into the wind and waves exceeds that when the antenna is looking downwind in both cases. The measured currents include a shadowed version of the surface wave orbital velocity and therefore are much larger than the actual currents. We interpret the upwave/downwave difference as being due to breaking wave effects, however.

References

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