

Airborne Measurement of the Space/Time Properties of Waves in the Coastal Zone

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LONG-TERM GOAL

Our long-term goal in this project is to utilize a newly developed airborne microwave technique to monitor the propagation of surface waves longer than about 30 m from the deep ocean into the coastal zone.

SCIENTIFIC OBJECTIVES

Our scientific objectives are to investigate the generation of forced waves produced by quadratic nonlinearities, the refraction of swell in shallow water, the possibility of determining bottom topography from refraction, and the effects of bottom topography and composition on the reflection and attenuation of swell propagating shoreward.

APPROACH

Our approach has been to fly a coherent real aperture radar (CORAR) on the CIRPAS Twin Otter aircraft in order to make images in a sidelooking mode of the waves propagating toward and away from shore and to measure their directional spectra and the accompanying wind speed utilizing a simultaneous rotating mode. By obtaining wave spectra from both the imaging and rotating modes, we can obtain the dispersion behavior of the spectral peaks and thus determine the order of the interaction that produced them. We are also attempting to extract currents from CORAR's rotating mode and compare them with currents simultaneously measured by a shore-based CODAR. We flew along with two NOAA radiometers that measured air/water temperature difference as well as wind speed and direction. Finally, we flew in formation with a NOAA LongEZ airplane that measured atmospheric turbulence and directional wave spectra at low altitude. We will compare our measurements with theirs.

WORK COMPLETED

Following the initial funding of this project in March 1997, work first focused on modifying the existing hardware and software to allow CORAR to operate at the speeds of the Twin Otter and to operate in both the rotating and imaging modes simultaneously. The modified system was flown for the first time on the NPS Twin Otter off the coast of Florida in March 1999. After we corrected problems

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found during this flight series, we flew CORAR in the main experiment in November and December, 1999. The system worked well except that a timing problem that was not discovered during the experiment kept us from properly filtering the signal from the rotating system. This will limit results from this system but should still allow the objectives of the project to be addressed.

Figure 1 below shows CORAR mounted on the Twin Otter as it was used in North Carolina during the main experiment of SHOWEX. The gray cylindrical object beneath the fuselage that can be seen just behind the left wheel is the radome for the rotating antennas. The white sidelooking antennas (four feet long) are seen just above the radome directed to the left of the aircraft. The white pod just behind the door of the aircraft houses NOAA's 37 GHz polarimetric radiometer. Another pod with a vertical slot in it can be seen on the end of the wing. This houses NOAA's scanning 60 GHz radiometer whose purpose is to measure the air/sea temperature difference.



Figure 1. CORAR and NOAA's radiometers mounted on the NPS Twin Otter in North Carolina in November, 1999.

RESULTS

Two-dimensional wave height and slope spectra as functions of wavenumber have now been extracted from both the sidelooking mode (SLR) and from the rotating mode (SCAT). Those from SCAT require a modulation transfer function to be specified and are less reliable, at least in intensity, than those from SLR. Therefore, we will illustrate our results here using the SLR measurements.

Figure 2 below shows wave height and wave slope variance spectra obtained from the SLR mode on November 16, 1999, during SHOWEX. The top two panels show directional spectra; north is up. The

flattening of the slope spectrum in the lower left corner shows the limits of the wavenumber range of the system. The lower two panels show these spectra integrated over all azimuth angles. Dashed lines in these panels indicate k^{-4} for the wave heights and k^{-2} for the wave slopes. Mean square heights and slopes have been calculated for these spectra and are shown in the figure.

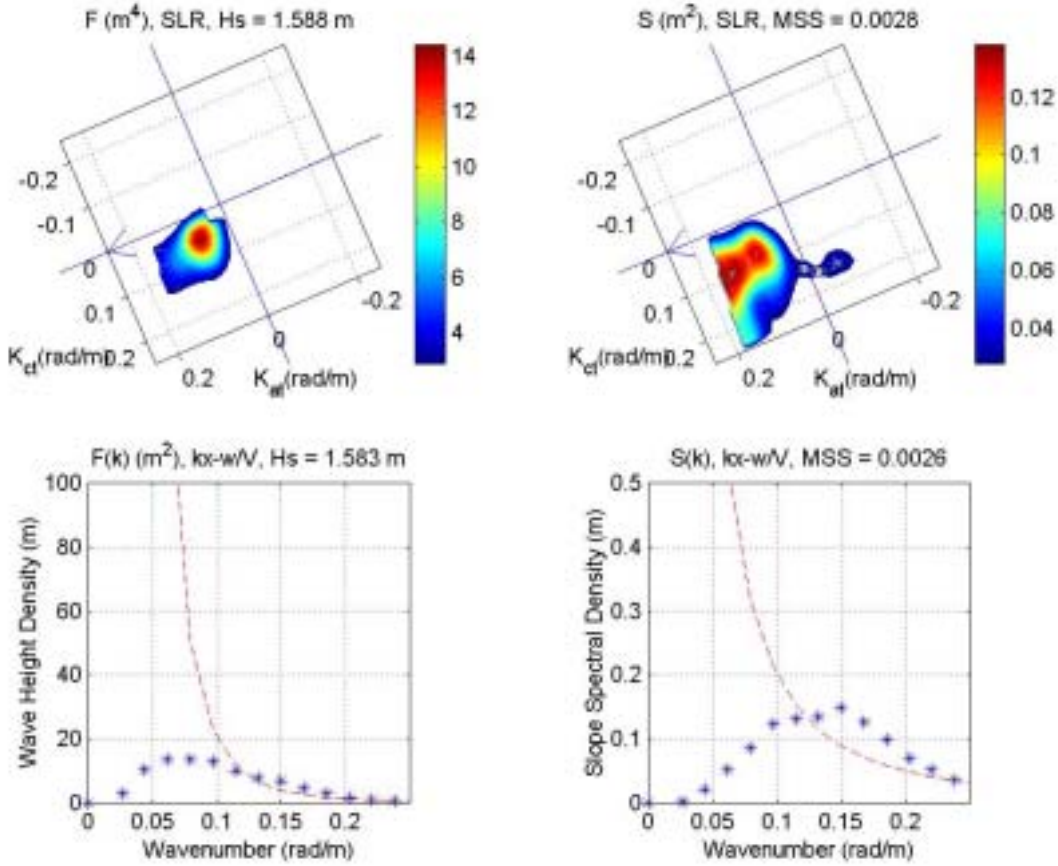


Figure 2. Directional wave height and slope spectra obtained from CORAR's sidelooking mode during SHOWEX (top panel) and the same spectra averaged over all azimuth angles (bottom panel).

Spectra such as these were collected off the coast of North Carolina every three kilometers along the flight tracks on 17 days in November 1999 during the main SHOWEX experiment. In addition, neutral wind speed and direction were also estimated every three kilometers using mean cross sections obtained in the SCAT mode. These were obtained using a model function that combined the NSCAT2 model function with the low-wind-speed measurements made from an airship by Plant et al. (1998).

The upper panel of Figure 3 shows the wind speeds and directions measured every three kilometers on November 16, 1999, the mean values over all measurements being indicated above the panel. The wind was blowing offshore at a rather large angle to the normal to the coastline, which is about 70 degT. In a situation such as this, Donelan et al. (1985) have shown that the wave direction is not in the direction of the wind. Rather there is competition between the reduced wind velocity component in the wave

propagation direction and the change in fetch with azimuth angle. This competition determines the direction of the dominant waves in the spectrum. The direction of wave propagation in deep water may be found by maximizing the function $x^{0.426} \cos\theta$ where x is the fetch at an angle θ to the wind. The middle panel of Figure 3 indicates this direction computed from the wind and coastline directions. The bottom panel shows the direction of propagation of the longest dominant waves in our wave slope spectra. Clearly, in the deep water well offshore, these directions match the predicted wave direction rather well. As the shoreline is approached, however, the wave direction turns to become more normal

Mean Wind Speed = 7.2 m/s, Mean Wind Dir (To) = 133.8 degT

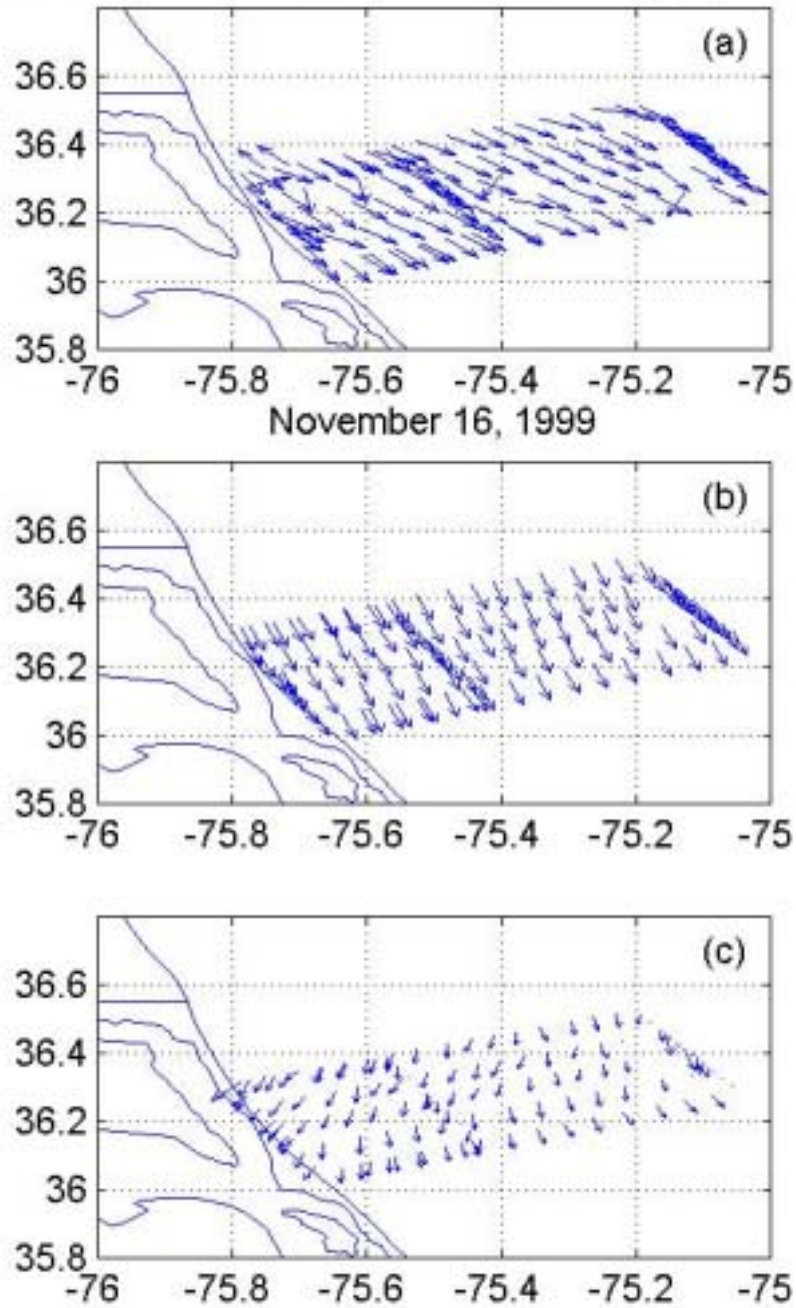


Figure 3. Top panel – Neutral wind velocities obtained from CORAR's rotating mode. Middle panel– Wave propagation direction in deep water predicted by Donelan et al. 1985 based on the wind and coastline direction. Bottom panel–wave propagation directions determined from CORAR's sidelooking mode.

to the coastline. It therefore appears that this is a situation where an offshore wind produces waves that refract to come back onto shore.

We are now in the process of checking other days in our data set to see if this is a common occurrence. We are also attempting to determine if these observed refraction effects can be used to estimate the depth of the water as a function of distance offshore.

Clearly the measured wave directions are not perfect, so the question is whether they are measured accurately enough to enable a sufficiently accurate determination of bottom topography. We are also in the process of determining the reduction in wave amplitude as these waves propagate toward the coastline. Finally, we are attempting to determine whether any information can be obtained on wave dispersion relations by comparing wave propagation directions in SLR and SCAT spectra.

IMPACT/APPLICATION

This project will shed new light on the interactions that occur when long ocean waves propagate onto continental shelves. In addition to this scientifically interesting impact, the results will also allow an assessment of the feasibility of determining ocean conditions near denied coastlines by means of coherent radars mounted on remotely piloted vehicles.

TRANSITIONS

CORAR has not yet been transitioned.

RELATED PROJECTS

This work is a direct outgrowth of research funded under the core program of the Space and Remote Sensing Program.

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