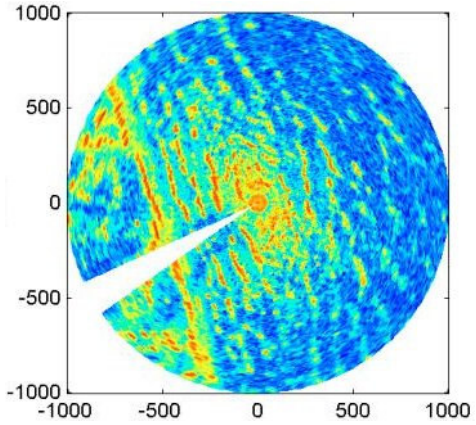
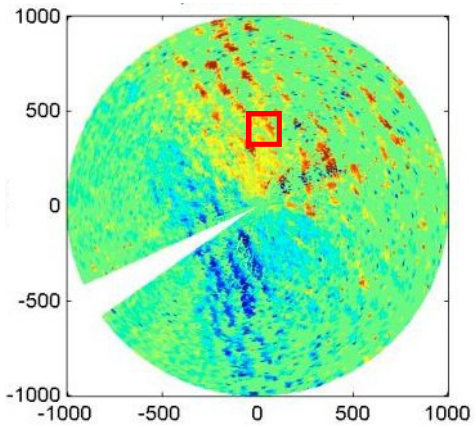


Traditional radar video image of ocean waves. Red box shows location of a typical window for 3D-FFT analysis for W-K



New Doppler image of radial velocity and mean currents. Red box shows typical size and location of window chosen for 3D-FFT analysis that results in W-K directional ocean wave spectra.

ISR

Imaging Science Research, Inc.

www.isr-sensing.com

ISR Coherent Marine Radars

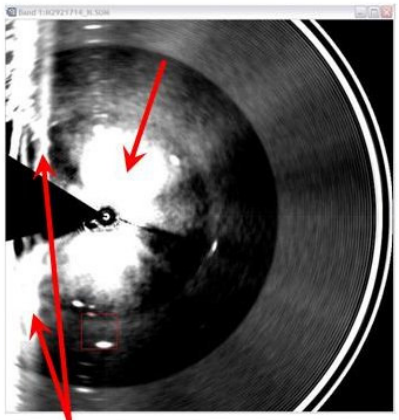
Our coherent marine radar (COHrad) offers new technology to measure surface currents and wave spectra by means of orbital wave velocity measure, a first. Backscatter intensity is used by other systems with standard marine radar approaches that require an empirical MTF to scale spectral echo strength to wave height spectra, which is sensitive to a number of environmental parameters. Our Doppler measure is direct and does not suffer from this environmental dependence.

The package is based on a SiTex/Koden pedestal and antenna, but with internal RF components replaced with our transceiver and a 5-watt solid state power amplifier. Rather than 25 kW simple pulse, we use an FM chirp pulse at very high PRF with pulse summing and pulse compression to achieve similar sensitivity. Range resolution of up to six times higher than standard marine radars is possible with the ISR transceiver system. Results shown here use a 30 MHz BW, 2.5 x that of marine radar.

The radar produces a standard video image (upper left), as well as a Doppler image (mid left). Using a 1-kHz PRF, Doppler measures radial velocities of ~ 8 m/s unambiguously, as shown here. The Doppler shift is a result of mean currents + Bragg phase speed + orbital wave modulations. For the data on the left there was a mean current that is estimated on the back page.

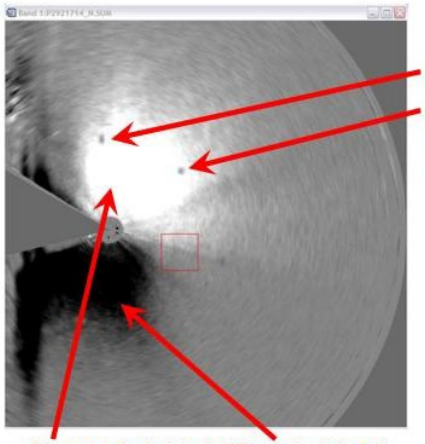
On the right are summed video and Doppler images that show bar structure and mean wind direction at the top, and the radial velocity vs azimuth below. Note fixed surface echoes show up better in Doppler than in magnitude

64-Image Magnitude sum



Offshore Bar; Mean direction of short wave Bragg scatterers align with northerly wind direction

64-Image Velocity sum



Fixed surface echoes show zero-mean radial velocity

Approach (white) / Recede (black) mean radial current component

(Synopsis of:) Coherent Marine Radar

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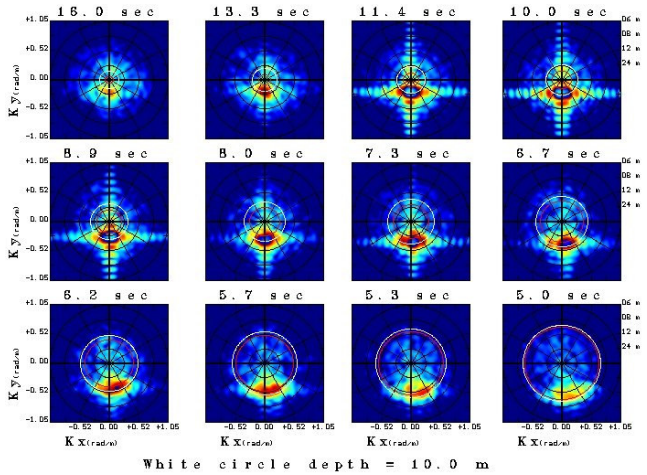
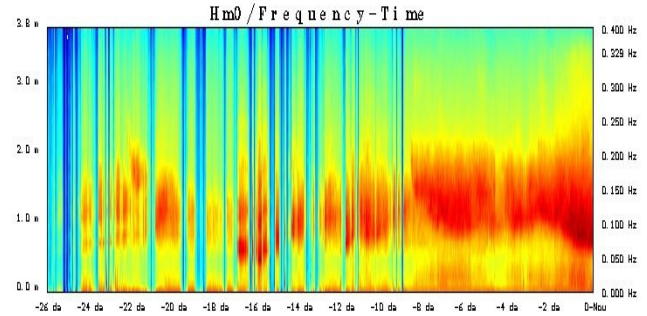
ISR Coherent Marine Radars

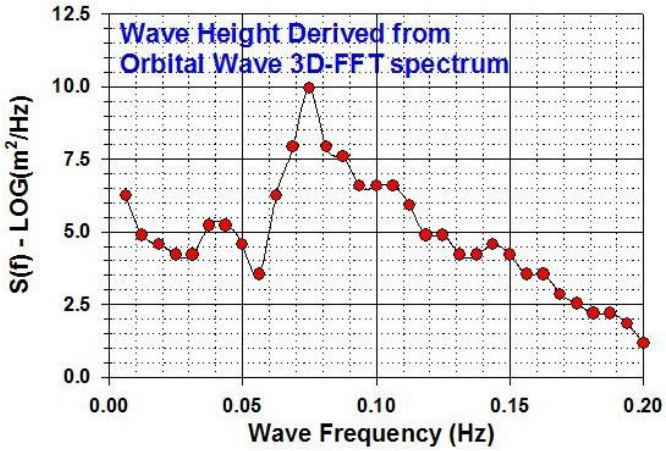
Ocean wave spectra are derived from 3D-FFT processing of 64x64 windows from sets of 64 consecutive rotations to produce Ω-K spectra, examples of which are shown below for 12 of 32 ocean frequencies. Those below are from radar video images, but the Doppler results look similar, as they are both power spectra.



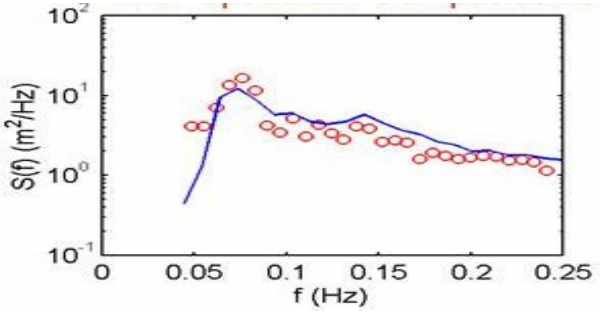
If the energy is summed around the peak in each K-spectrum, then a frequency spectrum is generated, integrated over all azimuths, and is plotted below as a time series covering 26 days using hourly acquisitions. Gaps in the data that show as vertical blue streaks represent times when the wind has dropped below 3 to 4 m/s, and insufficient radar echo was available to conduct an analysis. This is particularly true in coastal areas where surfactant may suppress short capillary waves that are required for good

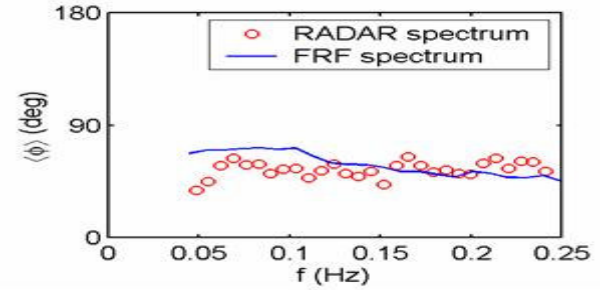


Below is shown a frequency spectrum derived from Doppler image data from the 2009 Veteran's Day storm during the passage of Hurricane Ida off the Outer Banks, NC. This is one vertical cut from the time sequence similar to bottom left.



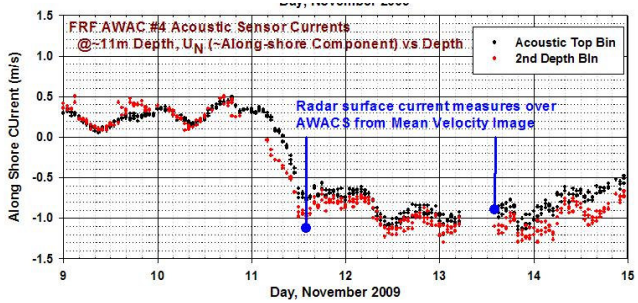
An independent analysis by colleagues at the University of Michigan using a slightly different approach show similar results, and are compared with USACE FRF pressure array frequency spectra. They show similarities to our results, and a good comparison with the 3-hr averaged surface truth. Their azimuthal comparisons show below.





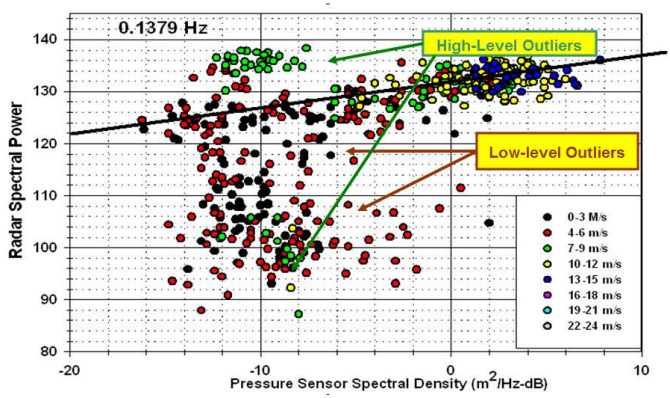
Surface current estimates

From summed Doppler data over 256 rotations similar to that shown on the opposite page, we chose the maximum Doppler shift in the approach and recede directions (exclusive of the enhancement in the breaking region), subtracted the Bragg phase velocity of 22 cm/s, and have plotted two results below with comparisons with FRF AWACS bottom pressure sensor current estimates over the same period.



Standard Marine Radar Approach Errors

Spectra derived using radar video image analysis suffers from errors in the MTF used to scale radar to ocean spectra. Outliers below are due to winds opposite wave direction, errors in wave



(Synopsis of:)

Coherent Marine Radar Measurements of Ocean Wave Spectra and Surface Currents

Presented at:

Oceans Sciences 2010