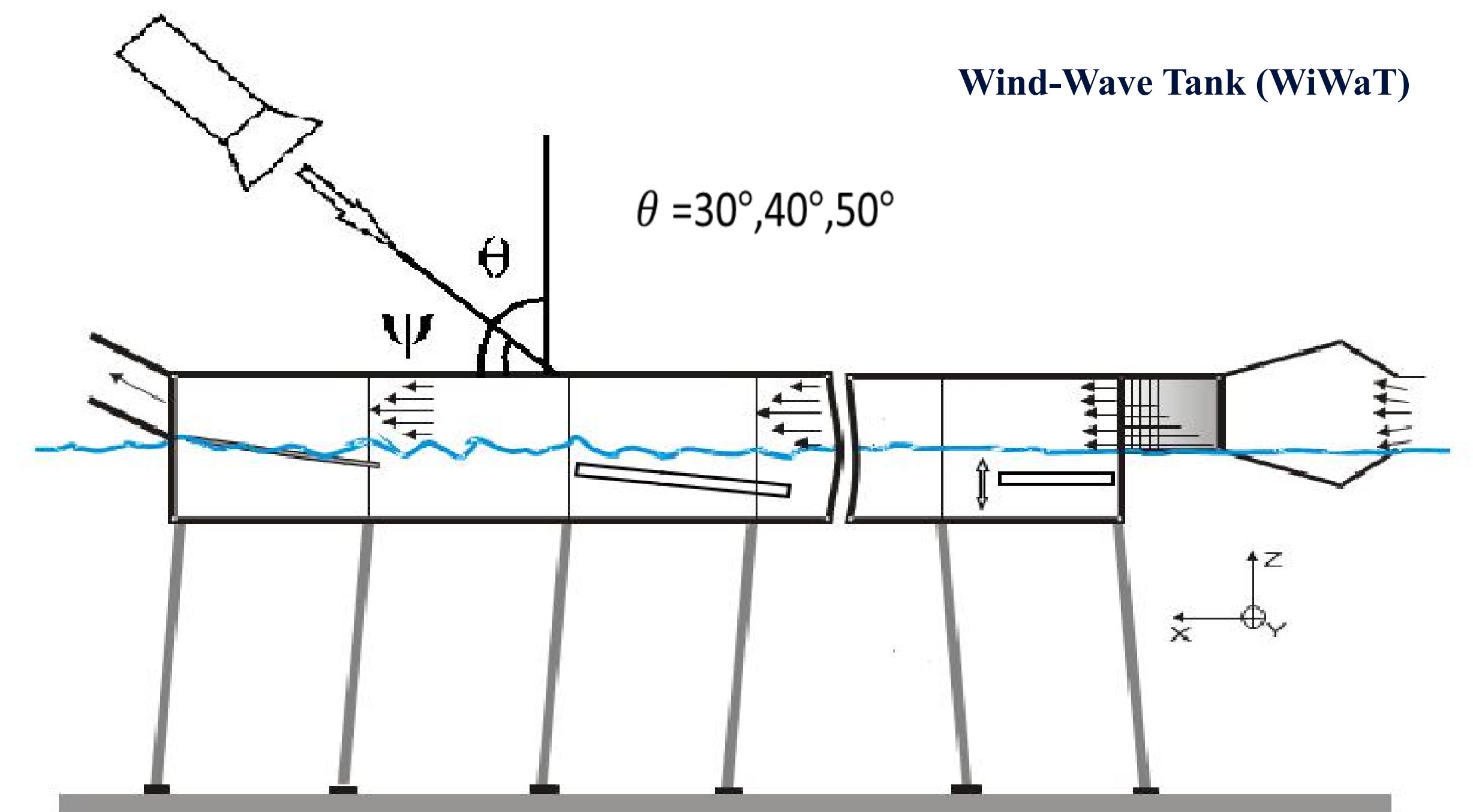


Summary

The work is concerned with the study of the breaking surface wave effect on the intensity and spectral characteristics of a scattered radar signal in laboratory conditions in a wide range of wind speeds.

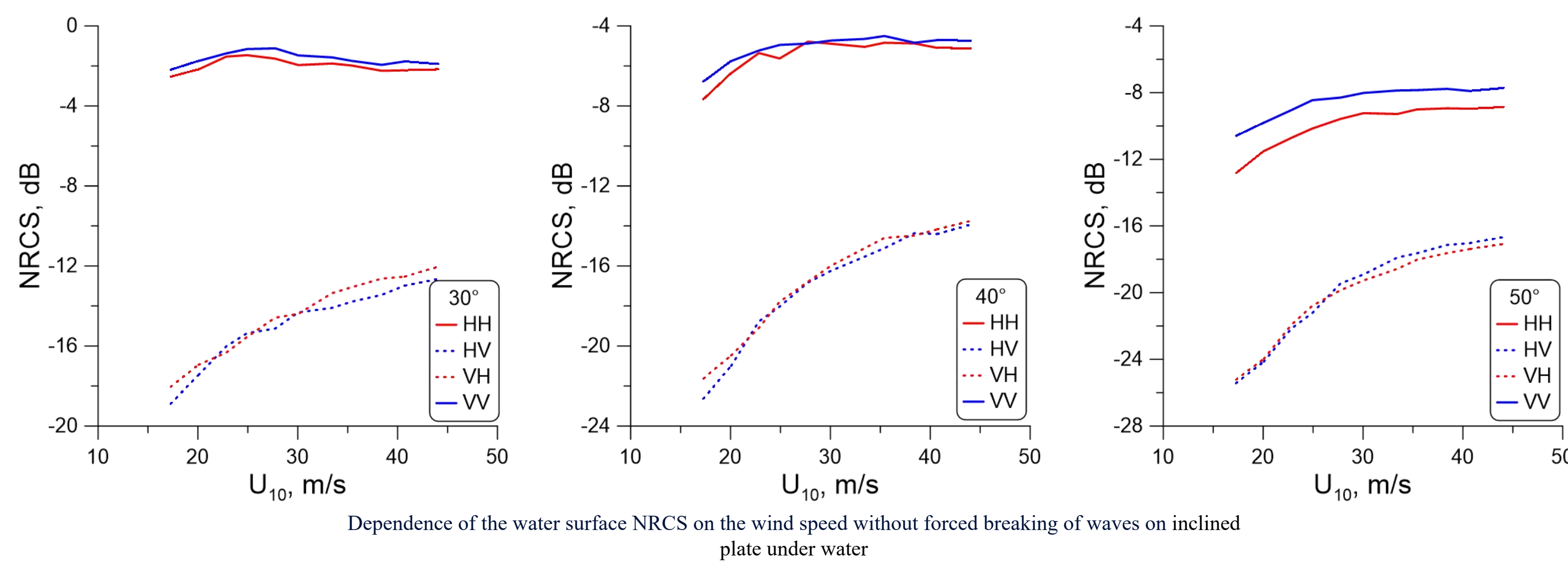
Two series of experiments were carried out on the reconstructed TSWiWaT wind wave flume of the IAP RAS. In the first case, wind waves in deep water, developing under the action of a fan generated wind, were studied. In the second case, a train of three waves was generated at the beginning of the channel, with the fan turned on, in order to simulate shallow water an inclined plate was placed under water before the measurement area. As a result, the breaking waves occurred at a fixed point and at weaker winds compared to the first case. The characteristics of the signal scattered by the breaking waves were investigated using an X-band coherent Doppler scatterometer with a wavelength of 3.2 cm

The scattering of the co- and cross-polarized microwave signal on the wave breaking region was measured at different wind speeds (U_{10} from 15 to 42 m/s) and incidence angles (from 30° to 50°). To interpret the measured radar signal and record the wave characteristics, an array of three wave gauges was installed before an inclined plate under water. It was found that the structures generated during the breaking of waves on the water surface have a characteristic size of the order of several centimeters and have a significant radar cross-section (RCS).



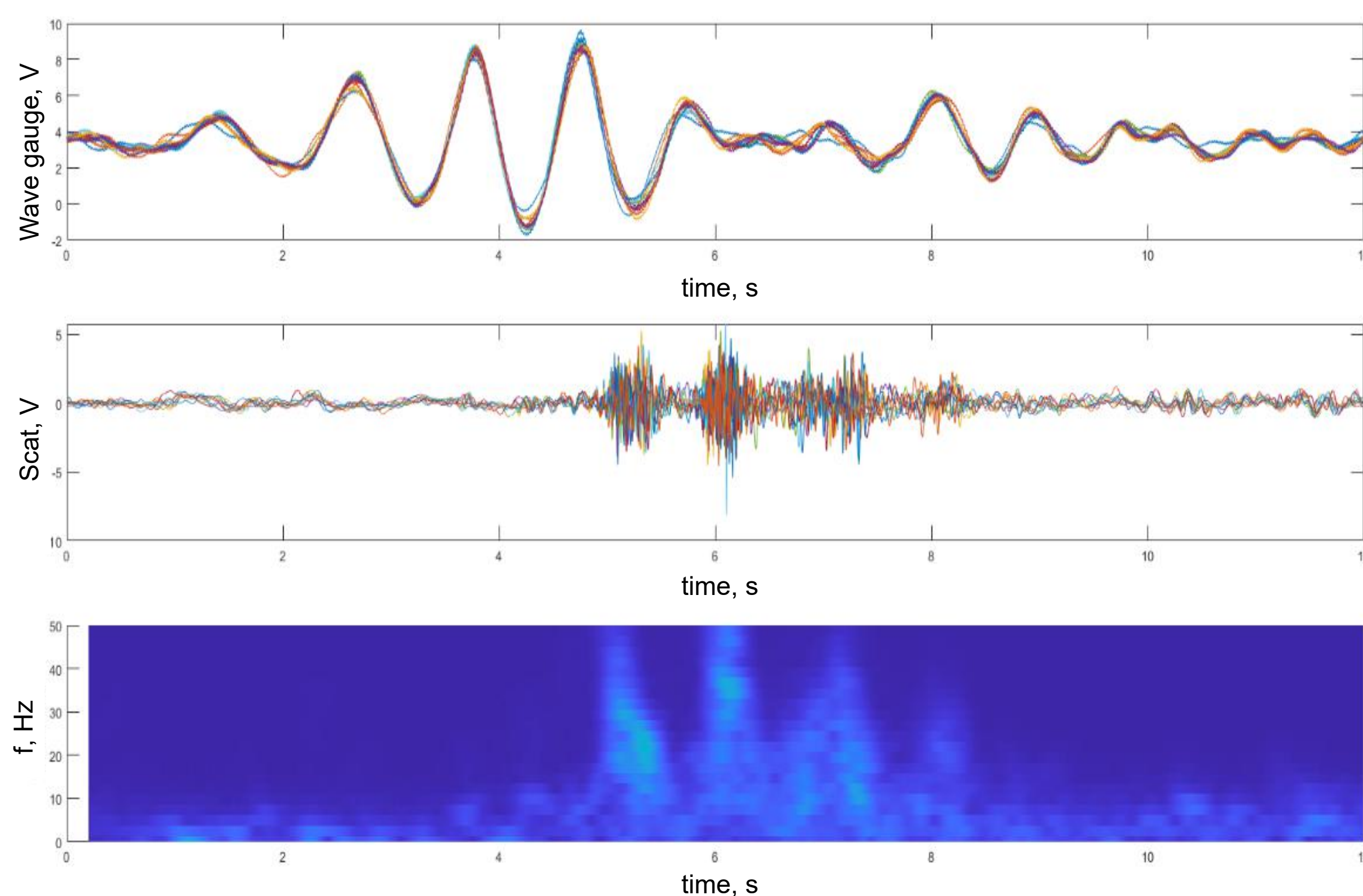
Experimental Setup:
The dimensions of the observation cross-section – 40x40 cm
Incidence angles $\theta = 30^\circ - 50^\circ$
The distance to the target – $D=3.16$ m

NRCS of the water surface

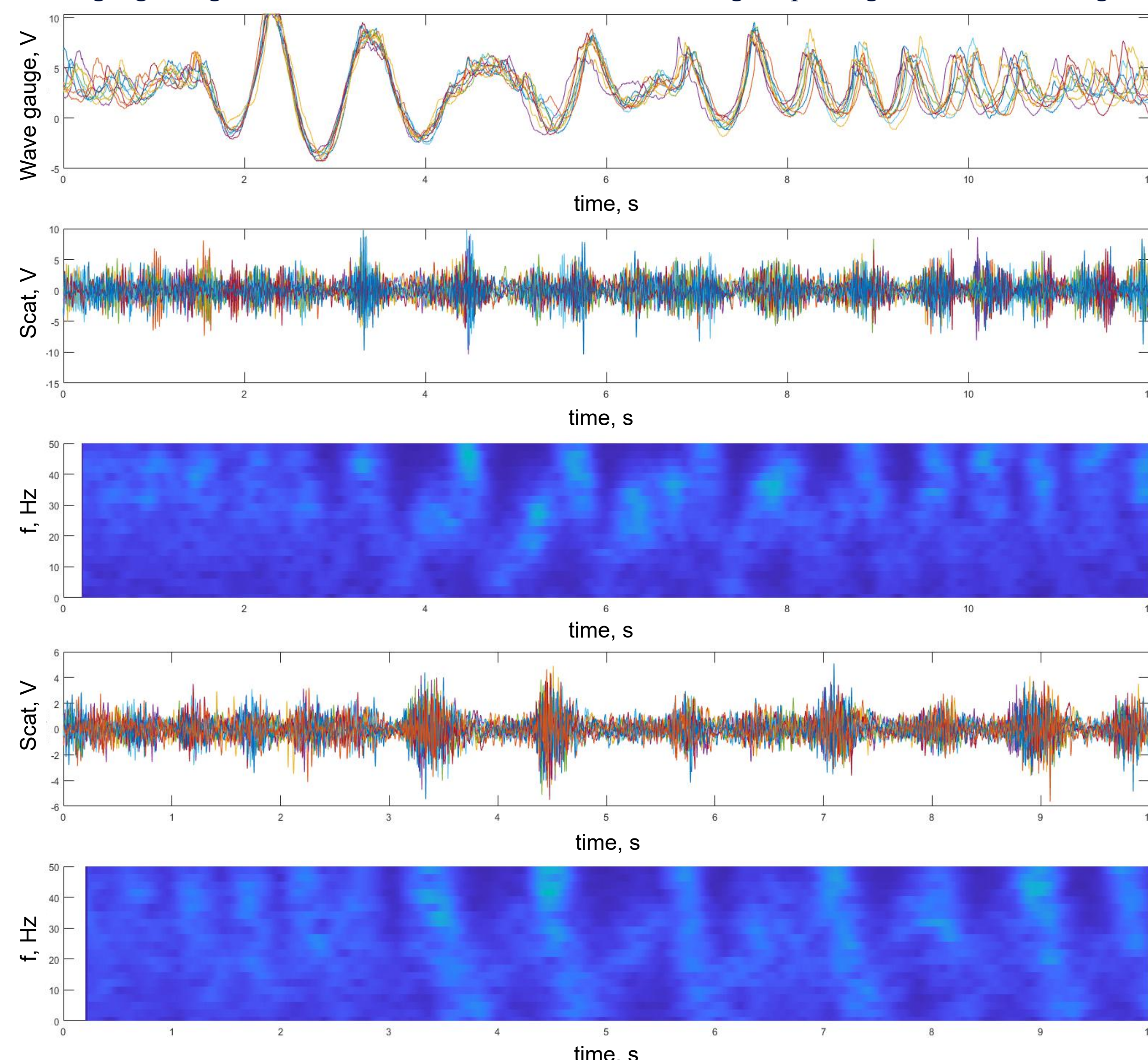


Spectrograms of a train of breaking waves

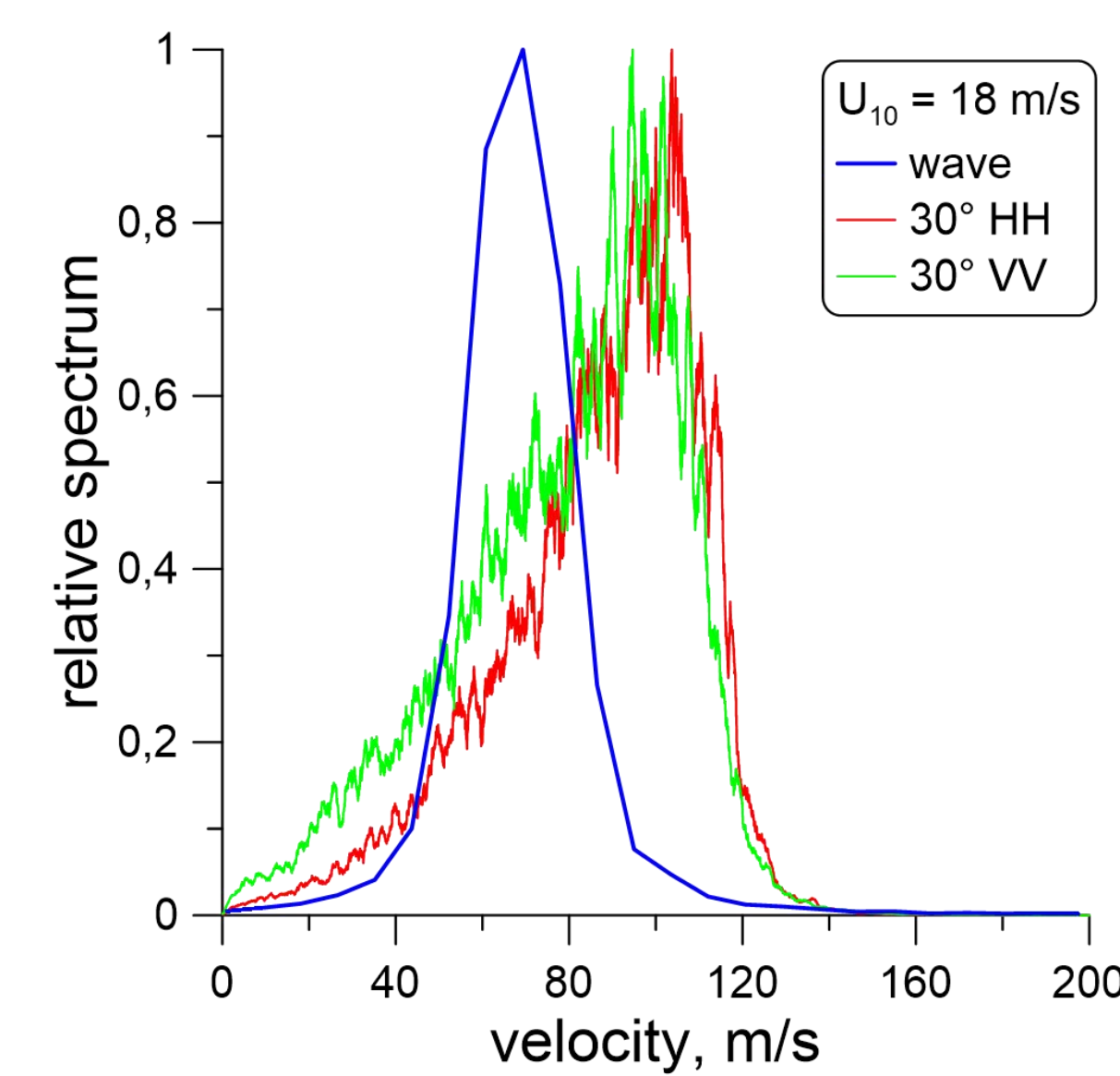
The figures show superimposed oscillograms of wave trains obtained from the wave gauges installed before the breaking zone, as well as from various channels of the scatterometer and their spectrograms. The shift along the horizontal axis is determined by the time the wave travels to the region of breaking. It is seen that the structures generated during the breaking of waves have a characteristic size of the order of several centimeters and have a significant RCS. After passing through the investigated region of the breaking crest of a long wave, the backscattering from the water surface decreases in comparison with the mean value observed during chaotic breaking.



The surface waves generated by the wavemaker, there is no wind. From top to bottom: recording from the wave gauges, signal from the scatterometer, ensemble-averaged spectrogram of the radar signal

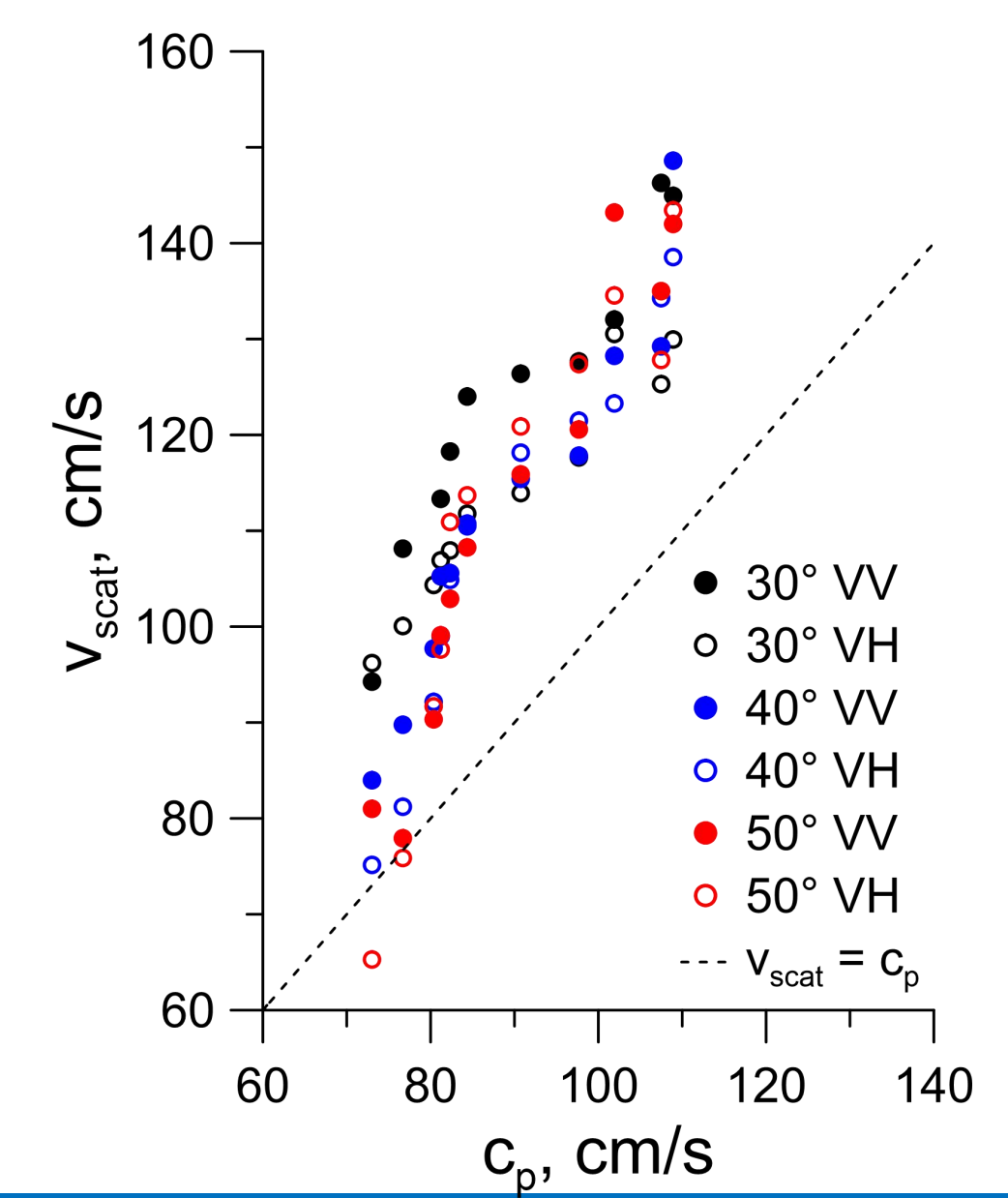
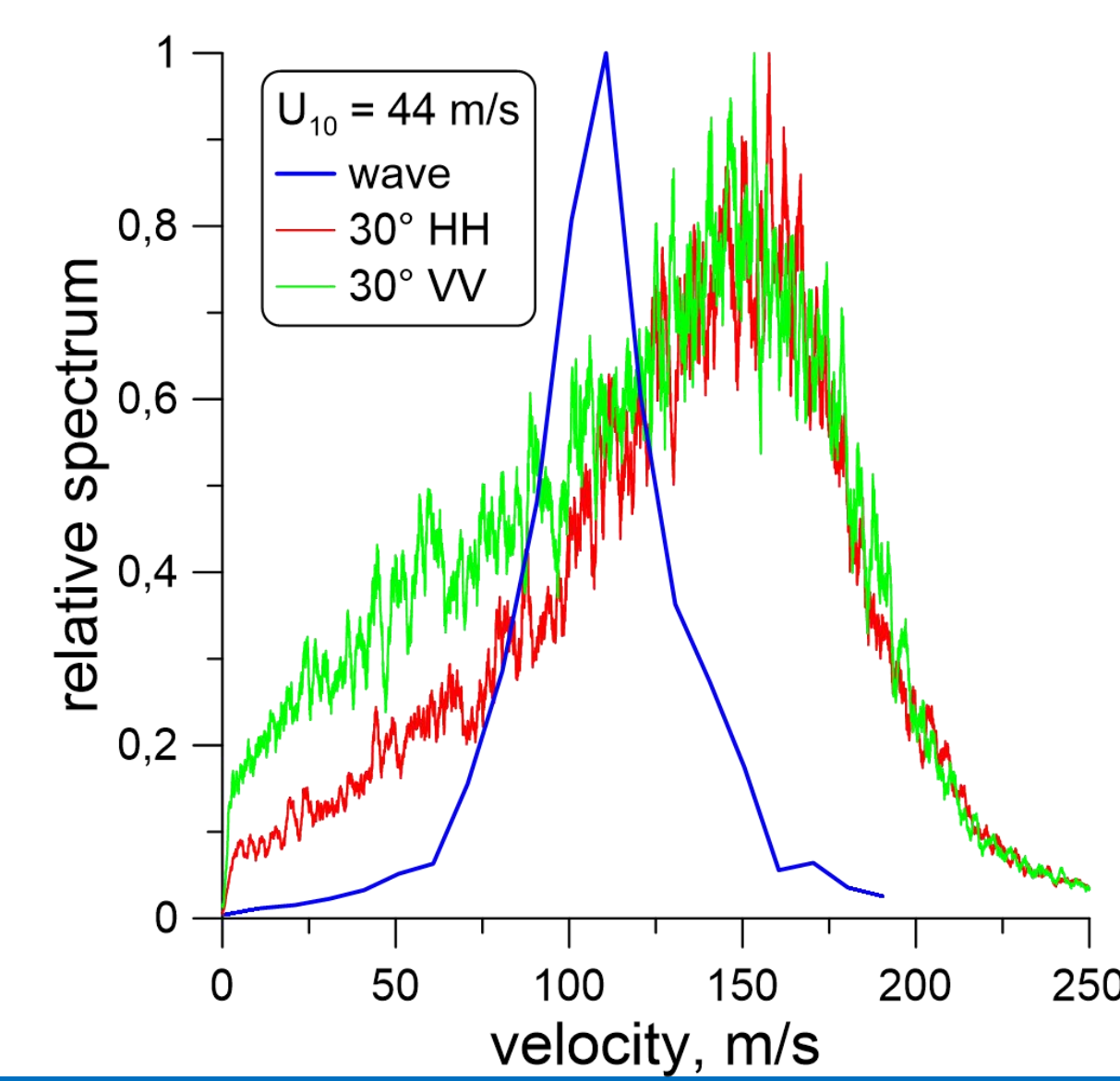


The surface waves generated by the wavemaker, wind speed $U_{10} = 38$ m/s. From top to bottom: recording from the wave gauges, signal from the HH channel of the scatterometer, ensemble-averaged spectrogram of the HH signal, signal from the VH channel of the scatterometer, ensemble-averaged spectrogram of the VH signal



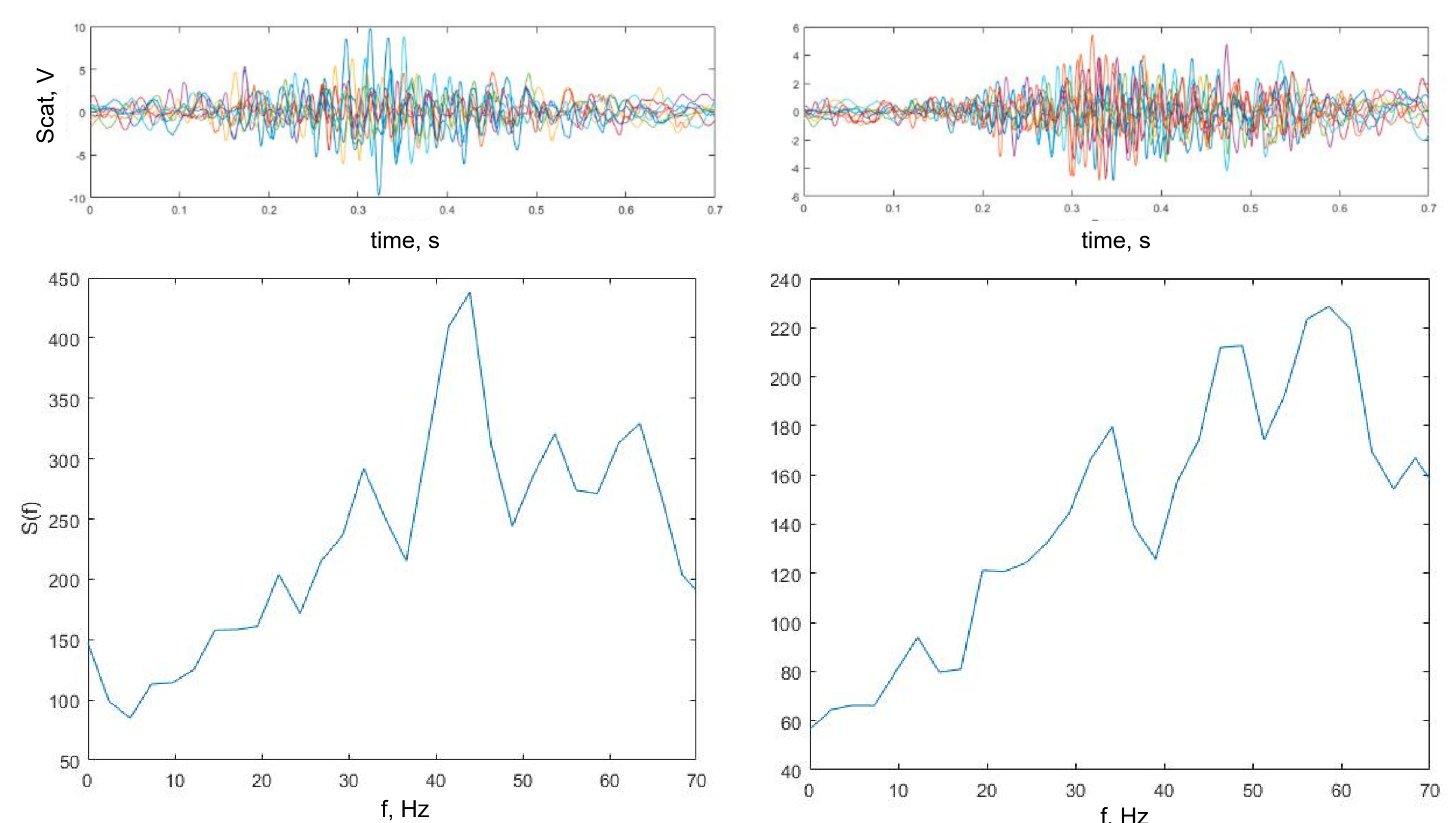
Doppler spectra of the radar signal

Doppler spectra analysis of the scattered signal and their comparison with the spectral distribution of the phase velocities of surface waves demonstrate that the speed of the scatterers is 10-15% higher than the phase velocity of the dominant wave. This means that the wave breakers are the main scatterer.



Single breaking wave

Passing a breaking wave. Oscillograms (top) and ensemble-averaged spectra (bottom) of the signal for direct HH (left) and cross VH (right) polarizations.



Conclusion

In strong winds, when generation of waves with wavemaker occurs together with regularly breaking wind waves, it has less effect on the scattered signal. After passing through the investigated region of the breaking crest of a long wave, the backscattering from the water surface decreases in comparison with the mean value observed during chaotic breaking. On the spectrogram averaged over the ensemble of realizations, noticeable peaks in the frequency range of 30–45 Hz are observed both for co- and cross-polarized signal only during the passage of breaking waves.

The spectrum of the signal on co-polarization has a more considerable maximum compared to the spectrum of the signal on cross-polarization. This feature was also observed during long-term signal accumulation without using a wavemaker.

It is shown that the spectrum of the signal obtained during the passage of the breaking wave has the same features as with prolonged signal accumulation in the regime of chaotically breaking waves. However, it can be studied in more detail with averaging over an ensemble of observations characterized by good repeatability.