University of Hamburg • Institute of Oceanography • Remote Sensing

SOPRAN III • Theme II • FINO-2

# Radar Backscatter Measurements on FINO-2

Martin Gade, Klaus-Werner Gurgel, and Detlef Stammer

The aim of our measurements is to provide an experimental data basis that allows to find a direct link between the radar cross section and the $CO_2$ transfer velocity. Since September 2011, continuous and autonomous measurements of the radar backscattering from the sea surface are being performed on FINO-2 using the Multi³Scat of the University of Hamburg. The scatterometer is working at five microwave frequencies (1.0 GHz, 2.3 GHz, 5.3 GHz, 10.0 GHz, and 15.0 GHz, corresponding to L, S, C, X, and Ku band, respectively) and at all polarization combinations (HH, HV, VV, and VH). Great efforts have been spent to maximize the signal-to-noise ratio (SNR) by removing the phase noise, which may be of the same magnitude as the ocean backscatter, particularly at high radar frequencies and low wind speeds. To complement the measured relative (i.e. non-calibrated) radar backscatter time series, synthetic aperture radar (SAR) images acquired by the radar sensors aboard the German TerraSAR-X and TanDEM-X satellites and the Canadian Radarsat-2 satellite are being used. Those images provide snapshots of the spatial variation of the radar backscatter at X band (TerraSAR-X) and C band (Radarsat-2) and, together with data from spaceborne scatterometers (Ku band; on QuikScat and OceanSat-2), enable us to put our time series in a greater (synoptical) context.

## Improving the signal-to-noise ratio by removing artifacts

The design of the Multi³Scat as a coherent Doppler-resolving system for positive and negative Doppler shifts requires that the Doppler zero frequency is mapped to some offset frequency. This requirement leads to a crosstalk signal at this offset frequency, partly generated by non-moving targets, partly caused by insufficient internal decoupling of the electronic components. This crosstalk signal usually is very strong and shows a tent-shape frequency response (Fig. 1, red curves) caused by (a) sampling errors, (b) FFT window function, and (c) local oscillator side band noise.

This crosstalk signal and its tent-shape frequency response are superimposed to the backscatter signal from the ocean surface, and in case of low backscatter it may dominate the Doppler spectrum. Removing this artifact is difficult, because its level is changing between measurements. However, its shape remains constant, and if the artifact is shifted to the correct level, it can be removed from the Doppler spectrum. The algorithm to determine this level makes use of correlation techniques and ordered statistics. Correct removal of the artifact has been checked using data from 11 days (about 72,600 Doppler spectra) covering different sea state conditions (calm sea to storm) by visual inspection.

The variation of backscattered power for the 5 frequency bands and 4 polarization combinations (VV, HH, HV, VH) during September 23, 2012 is shown in Fig. 2. Changes in backscatter due to the varying incidence angle can be seen clearly. The upper row in Fig. 1 shows Doppler spectra when the backscatter from the ocean surface dominates the signal. The lower row in Fig. 1 shows examples, where the artifact dominates the signal and needs to be removed.

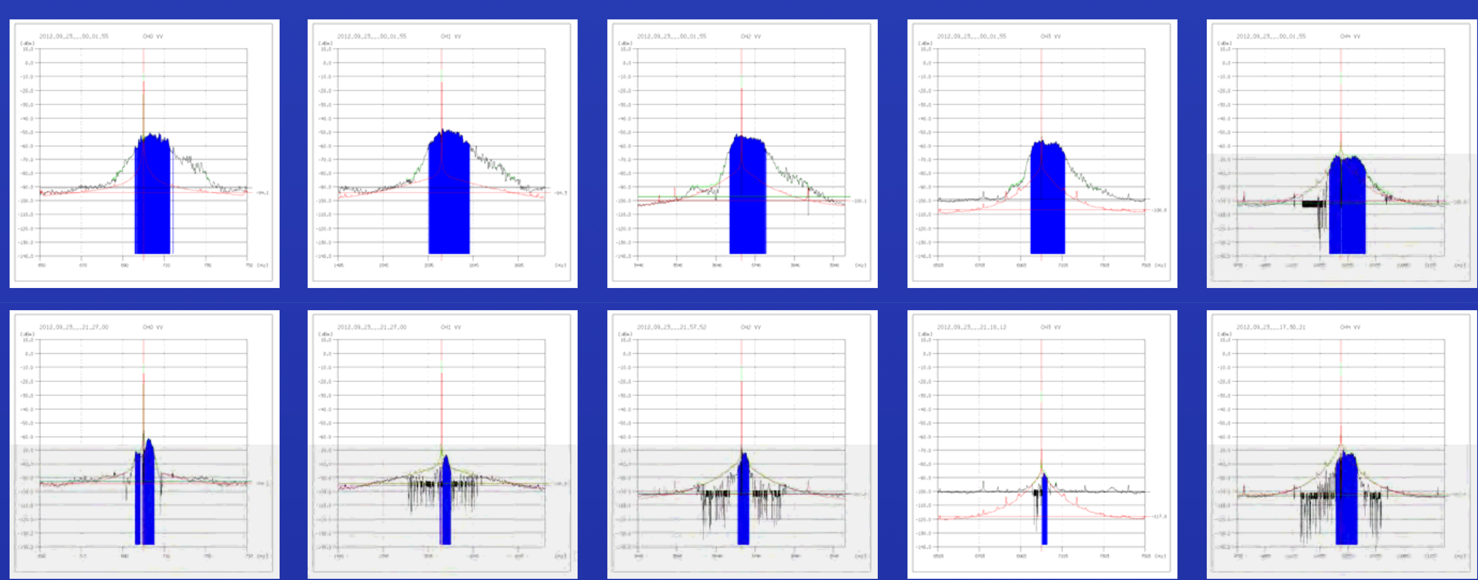

Fig. 1: Doppler spectra at L, S, C, X, and Ku band (from left to right) with strong (upper row) and weak (lower row) backscatter power. Green curves show the original spectra, red curves denote the artifact shifted to the correct level, black curves show the residual Doppler spectra with the artifact removed, blue colored areas mark the spectral part used for the derivation of the radar backscatter (Fig. 2)

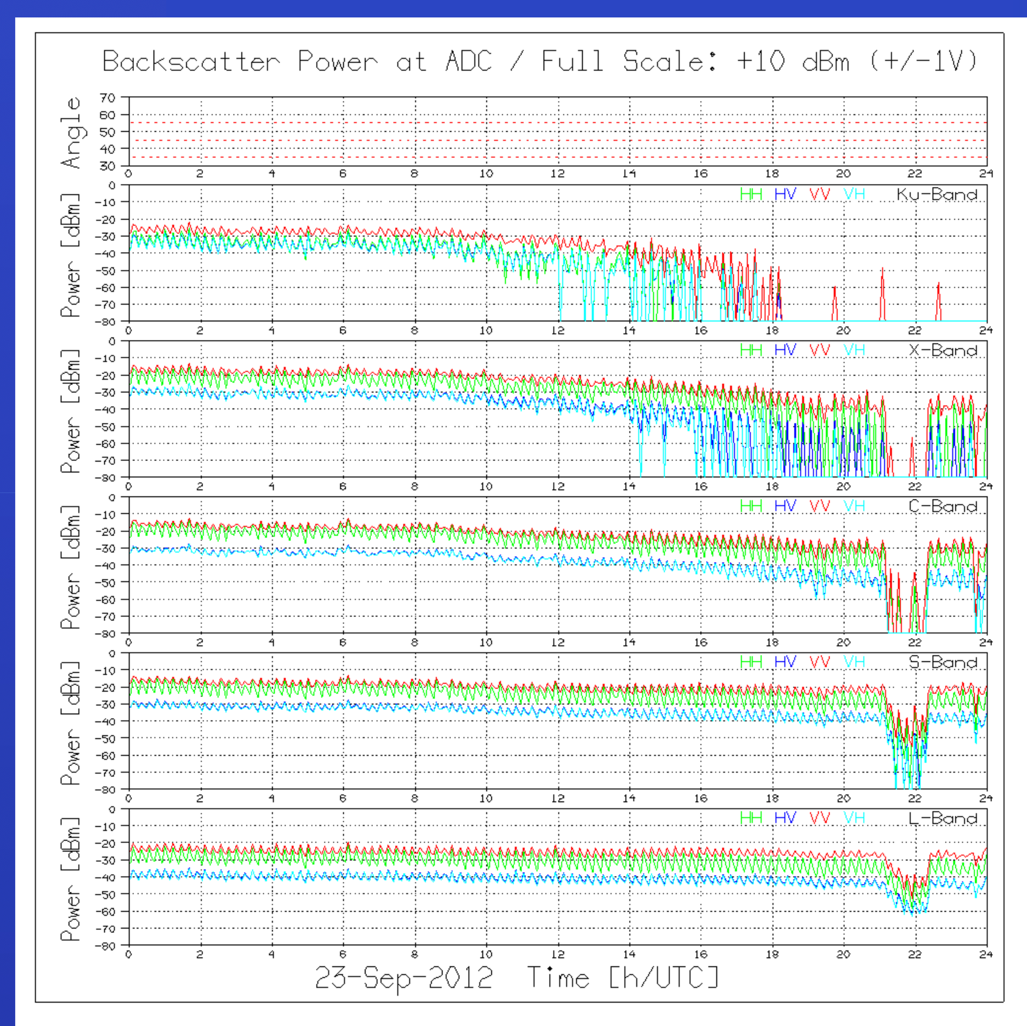


Fig. 2: Time series of the backscattered radar power for the five frequency bands (Ku, X, C, S, and L; from top to bottom), and for the four polarization combinations (VV, HH, HV, VH), measured on September 23, 2012

## Complementing data from spaceborne radar sensors

Radar data from spaceborne sensors such as the Synthetic Aperture Radars (SARs) aboard the German TerraSAR-X and TanDEM-X and the Canadian Radarsat-2 satellites, and the wind scatterometer (SCAT) aboard the Indian Oceansat-2 satellite are used to put our measured data into a greater context.

Fig. 3 shows radar backscatter time series measured by Multi³Scat on October 11, 2012. The data gaps around noon are due to maintenance work on FINO-2, during which the system had to be switched off. The strong variations of the radar backscatter in the afternoon hours, however, can be explained by marine biogenic surface films, which were encountered at the FINO-2 site and which were imaged by both the Radarsat-2 and TerraSAR-X SAR sensors (Fig. 4). Those surface films reduce the surface roughness and, thus, the radar backscattering, and they appear as dark elongated patches on the SAR imagery.

Also anthropogenic surface films such as mineral oil spills dampen the small-scale surface waves and cause dark patches on SAR images. As an example, Fig. 5 shows a mineral oil spill of more than 4.5 km² size, which was imaged close to FINO 2 (image center) on November 18, 2012.

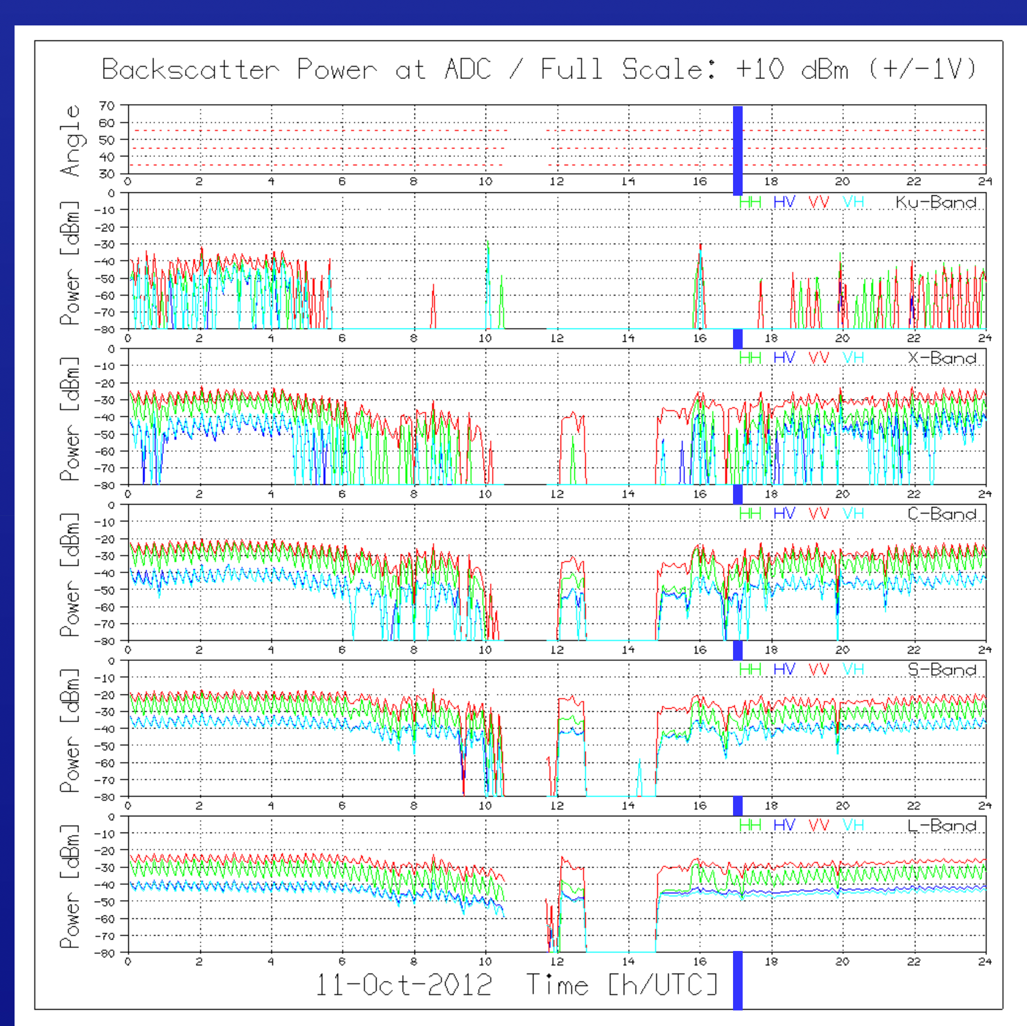


Fig. 3: Time series of the backscattered radar power for the five frequency bands (Ku, X, C, S, and L; from top to bottom), and for the four polarization combinations (VV, HH, HV, VH), measured on October 11, 2012. The blue vertical line denotes the acquisition time of the SAR images shown on the right (Fig. 5). Reductions of the radar backscatter at that time are likely to be caused by the marine surface films visible on the SAR imagery.

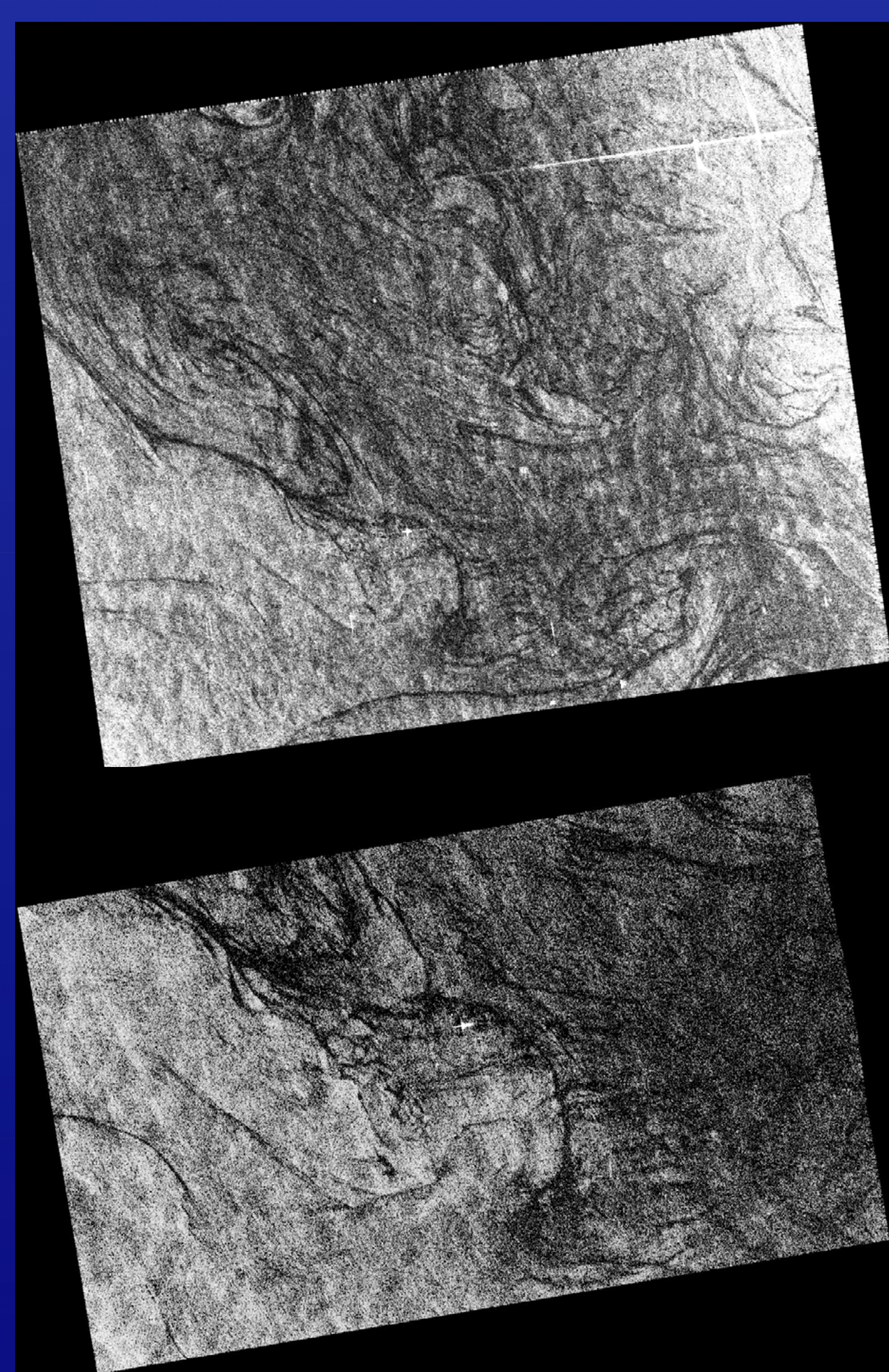

Fig. 4: Radarsat-2 (upper; C band, VV, 22.0 km × 17.8 km) and TerraSAR-X (lower; X band, VV, 15.3 km × 8.4 km) SAR images of the FINO-2 test site, acquired on October 11, 2012, at 17:05 UTC and 16:44 UTC, respectively. Dark elongated structures are due to biogenic surface films (slicks).

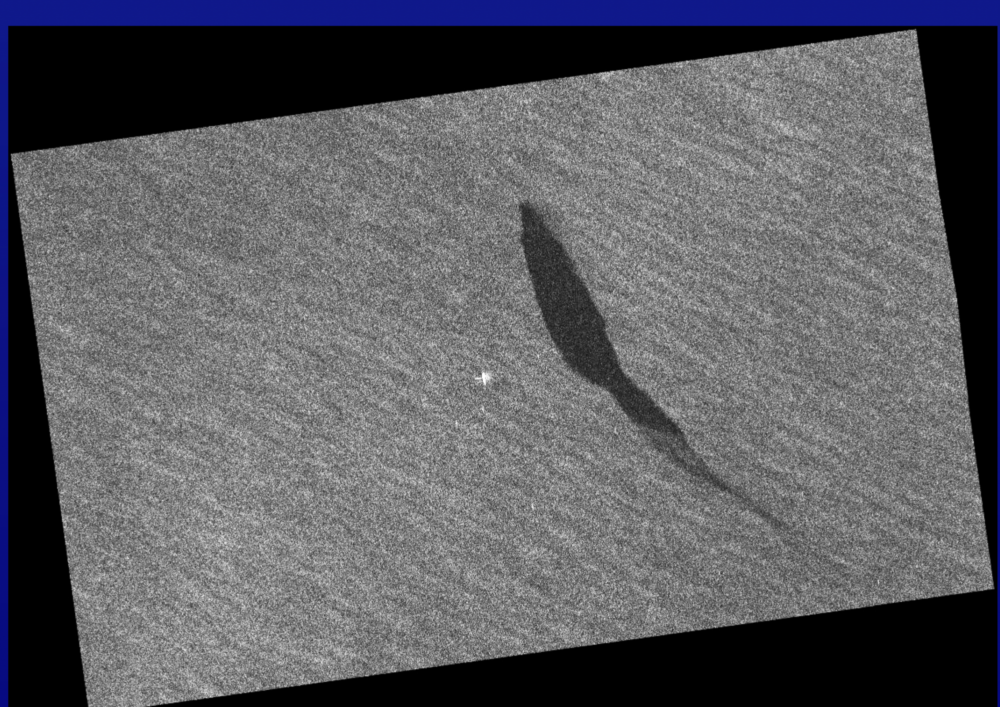

Fig. 5: TanDEM-X (X band, VV, 14.8 km × 8.7 km) SAR images of the FINO-2 test site, acquired on November 18, 2012, at 16:53 UTC. The dark patch is due to a mineral oil spill.

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