Linking CO_2 Transfer Velocity and Radar Cross Section of the Sea Surface on Regional and Global Scales

Detlef Stammer, Martin Gade, Klaus-Werner Gurgel

Institute of Oceanography / KlimaCampus Hamburg / University of Hamburg

Motivation

The goal of this sub-project is to provide an improved methodology for the determination of global gas transfer rates derived from satellite data. Example results from the ongoing long-term radar backscatter measurements on the research platform FINO 2 are presented. We demonstrate the capability of the newly designed and improved multi-frequency scatterometer (1 GHz – 15 GHz; L band – Ku band) "Multi³Scat" to operate autonomously on FINO 2 and to provide those data, which are needed to find a direct link between the radar backscatter from the sea surface and the gas transfer velocity.

Multi³Scat

Since late summer 2011, UHH's Multi³Scat is running autonomously on FINO-2. The scatterometer had been dismounted and brought to Hamburg for several improvements, after a severe malfunction had been detected (which had likely been caused by a lightning strike). The updated version has been siginificantly improved with respect to its safe autonomous operation, and first data were brought to Hamburg in mid October 2011. Since early 2012, Multi³Scat is operating at varying incidence angles, and the scatterometer measurements are complemented by optical and infrared (IR) imagery taken simultaneously from the radar footprint at the sea surface.

Data

The Multi³Scat data are brought to Hamburg, quality-checked and compressed, and stored on either magnetic tape archives (raw data) or network storages (compressed data). In addition, FINO-2 wind data and model current data (both provided by the Federal Maritime and Hydrographic Agency, BSH) are used, along with other meteorological (e.g. weather radar) data, for the interpretation of the measured radar backscatter parameters.

Figure 1 shows example data measured at low (left) and high (right) wind speed and at C band (upper) and Ku band (lower), VV polarization. Note the broadening of the Doppler spectra towards higher Doppler frequencies, which is due to an increase in wave breaking.

First Results

Figures 3A and 3B show four months of radar cross section (RCS) and radar Doppler shift, respectively, measured between mid September, 2011, and mid January, 2012, at all Multi³Scat radar frequencies (from top to bottom) and all polarization combinations (color coding). Correspondingly, Figure 3C shows the wind speed and direction at FINO-2, as measured at 31 m height, and Figure 3D shows modelled currents at the location of FINO-2.

Note the close correlation of wind speed (Figure 3C) and RCS, particularly at C and X band (Figure 3A). Multi³Scat is looking in westerly direction (270°), i.e., into the prevailing wind direction at FINO-2 (cf. Panel C, lower curve). It is such time series, in combination with concurrently recorded wind, wave and gas flux data, that will be used to gain better insight into the very radar backscattering mechanisms at the wind-roughened water surface, and thereby to develop an algorithm that directly links RCS and gas transfer velocity.

Phase III

During SOPRAN III, time series of the radar cross section will be analyzed at all frequencies and polarizations and correlated with CO_2 fluxes, CO_2 transfer velocities, wind speed and direction, wave state, and air and water temperatures, obtained previously by colleagues from MI and IOW. The measurements of radar backscatter and of gas fluxes will also provide an in-depth knowledge of the mechanisms responsible for the gas transfer under various environmental conditions. For the first time, the whole setup of SOPRAN field sensors will be used, including UHD's active thermographic instrument. The goal of the analysis is a thorough understanding of the dependencies of all measured parameters on the seasonal changes and in particular an improved understanding of the relation between radar backscatter and air-sea fluxes of CO_2. Results of the analyses of global scatterometer data as well as high-resolution synthetic aperture radar (SAR) data on a regional scale will aid our joint investigation.

It is expected that Multi³Scat will provide a unique dataset, which will form the basis for the comparative studies to be performed during SOPRAN's late Phase II and Phase III. Multi³Scat is anticipated to remain on FINO-2 until a full year of data are gathered, i.e., until all seasons are covered.

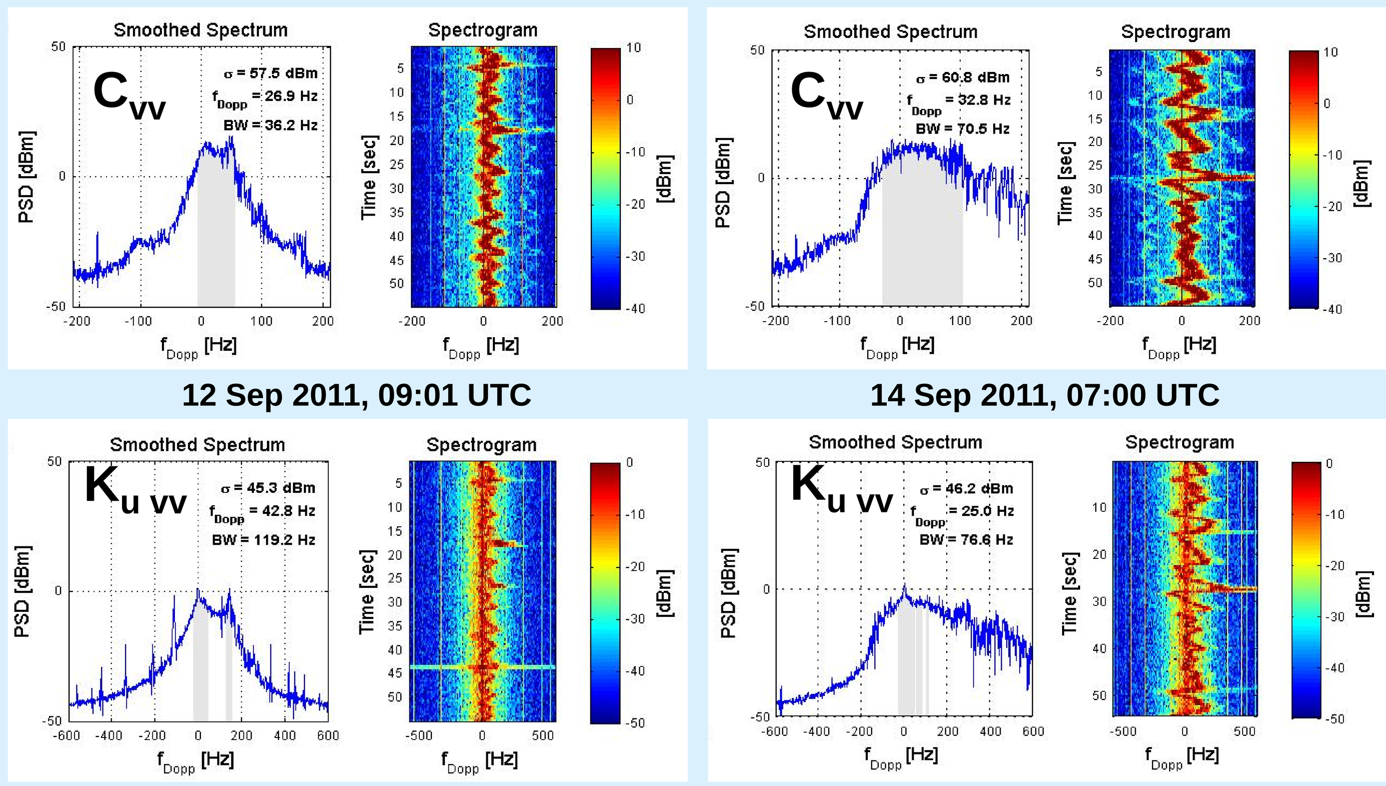
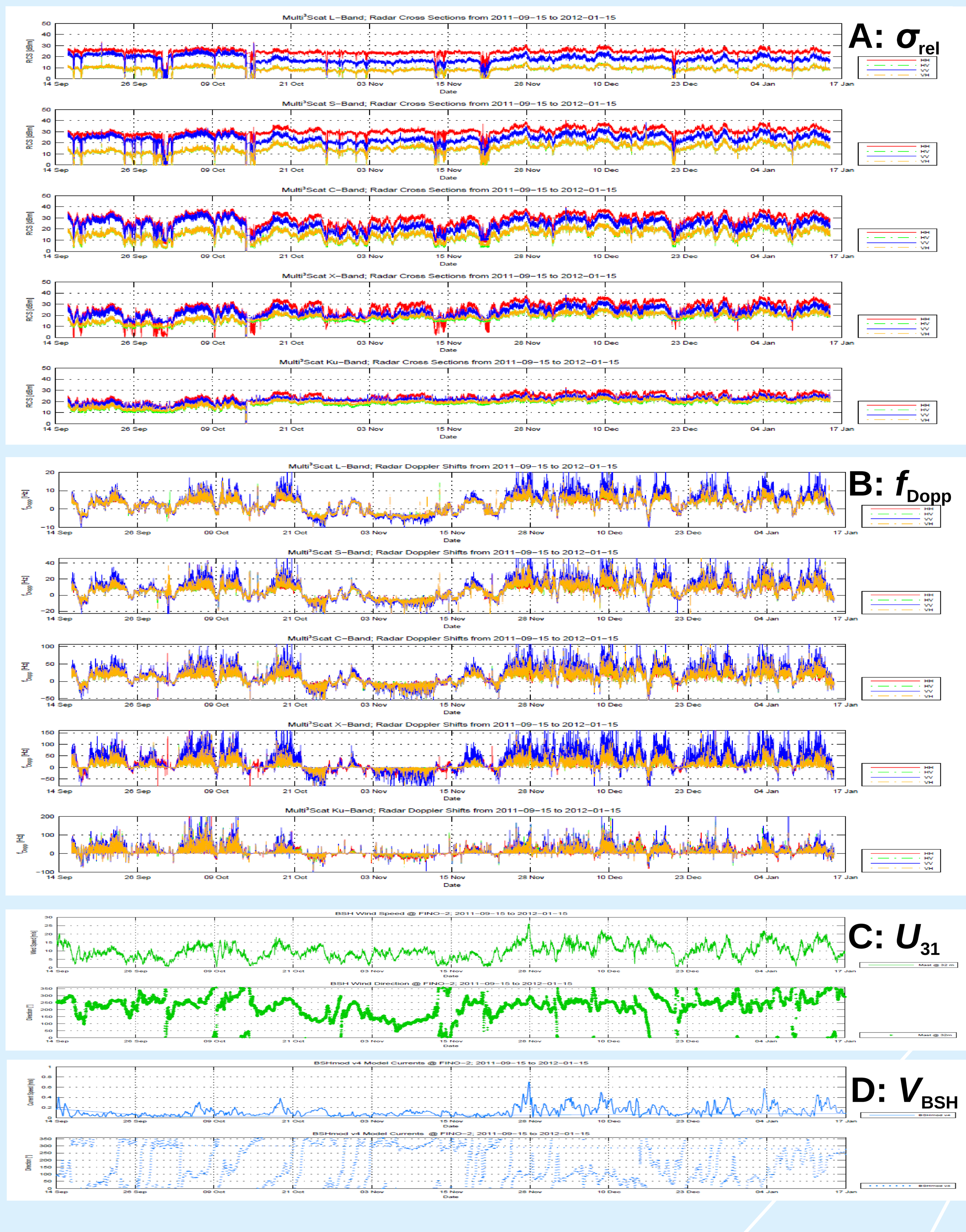


Figure 1: Example radar Doppler spectra measured at C-band (upper row) and Ku-band (lower row), VV polarization, and at low (left column) and high (right column) wind speed. The spectrograms in either panels show the modulation of both backscattered power and Doppler shift, by the long waves (swell).

Figure 2: Photograph of FINO-2, with the location of the scatterometer's footprint included. The small photograph shows the microwave antenna and video camera mounted on the mast at a height of 26 meters above mean sea level.

Figure 3: Time series of radar backscatter (σ_0, Panel A), radar Doppler shift (f_D, Panel B), wind speed and direction (U_{31}, Panel C) and model current and direction (V_{BSH}, Panel D), from mid September, 2011 until mid January, 2012. Multi³Scat data in Panels A and B are shown for L, S, C, X and K_u band (from top to bottom) and for HH, HV, VV and VH polarization (red, green, blue, yellow curves, resp.).



Acknowledgements

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