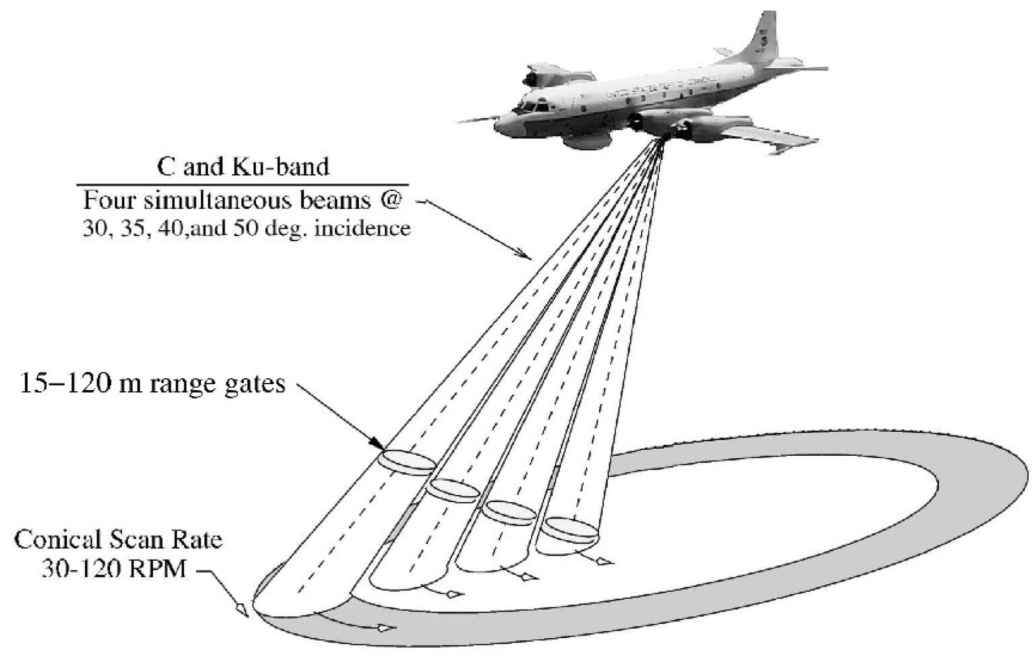
Airborne Cross-polarization Observations of the Sea-Surface NRCS in High Winds

J.W. Sapp, S.J. Frasier, P.S. Chang*, Z. Jelenak*, M. Baker*
Microwave Remote Sensing Laboratory, University of Massachusetts Amherst, Amherst, MA
*NOAA-NESDIS, STAR, Camp Springs, MD

Abstract

Airborne co- and cross-polarization observations of sea-surface normalized radar cross-section (NRCS) were conducted over the East Pacific during September 2011 and over the North Atlantic during January–February 2012. Observations were made using the University of Massachusetts' Imaging Wind and Rain Airborne Profiler (IWRAP) radar system installed on the National Oceanic and Atmospheric Administration's (NOAA) WP-3D research aircraft during one tropical cyclone and several winter storm events. The purpose of the experiments was to investigate the high-wind response of the sea-surface NRCS for VH polarization at C-band and Ku-band frequencies for two incidence angles each. A monotonic increase of approximately 2 dB over the range of wind speeds encountered (25–35 m/s) was observed the polarization ratio (VH/VV) at Ku-band. At C-band, the polarization ratio behavior mirrored VV NRCS suggesting the observations were limited by the finite cross-polarization isolation of the antenna..



Measurement Configuration

The IWRAP radar configuration on the NOAA WP-3D for this mission is shown at right. Two radars (one C-band and one Ku-band) scan conically below the aircraft at nominal incidence angles of 25 and 46 degrees off nadir and at a rate of 60 RPM. Each radar is capable of two simultaneous beams at different incidence angles. The radar beamwidths vary depending upon the incidence angle, but are typically in the neighborhood of 10 degrees. Both H and V polarizations are available for transmit and receive. For the Fall 2011 and Winter 2012 flights, we operated in an alternating VV and VH mode.

	Measurement Parameters
PRF	15.015 kHz
Antenna rotation rate	60 RPM
Nominal Incidence Angles (approx.)	25°, 46°
Polarization mode	Alternating VV and VH
Pulses per Polarization	126
Time per Polarization	8.4 ms

Experiment Description

For the Fall 2011 and Winter 2012 flight missions, it was desired to obtain cross-polarized (VH) sea-surface NRCS observations at fixed incidence angles. For comparison, co-polarized (VV) observations were collected simultaneously. This was achieved by transmitting/receiving alternating blocks of pulses in VV mode and in VH mode. Surface wind speeds were measured with the Stepped Frequency Microwave Radiometer (SFMR), operated by the NOAA Aircraft Operations Center aboard the WP-3D aircraft.

Preliminary Results

Preliminary results from the flights on 2011 September 28 and 2012 February 5 are shown below. In each pair of plots, estimated NRCS from the sea-surface in rain-free conditions is shown on the left; both channels (time-sharing the same receiver) are calibrated by adjusting the VV measurement at 25 m/s to match a VV GMF. The same calibration is then applied to VH. On the right of each pair of plots, the ratio VH/VV is shown. Where applicable, geophysical model functions are shown. For C-band, these include the GMF, CMOD5.N, and a VH/VV model from Vachon and Wolfe, 2011. For Ku-band, the GMFs shown are the IWRAP and Ku2011 (REMSS) models. Note that the IWRAP GMF at Ku-band is only valid above 25 m/s and the Ku-2011 model was developed for 53° incidence. Data was not collected at C-band during the Fall 2011 experiment.

These results show that while the co-polarized data collected by IWRAP are consistent with GMFs, the observed cross-polarized data from the ocean surface are not quite as expected. The observed polarization ratio is close to the polarization isolation of the IWRAP antenna, and the observed cross-polarization signal is also close to the noise level of the receiver. Thus, while we see a weak dependence with wind speed of the polarization ratio (VH/VV) at Ku-band, we cannot, at present, rule out the finite cross-polarization isolation of the antenna as a source of bias (larger bias at lower wind speeds). At C-band, the results appear to be limited by the isolation of the antennas. By filtering the received signals to ensure the received signal comes through the central portion of the antenna beam, some improvement in the polarization isolation is possible. This will be investigated further.

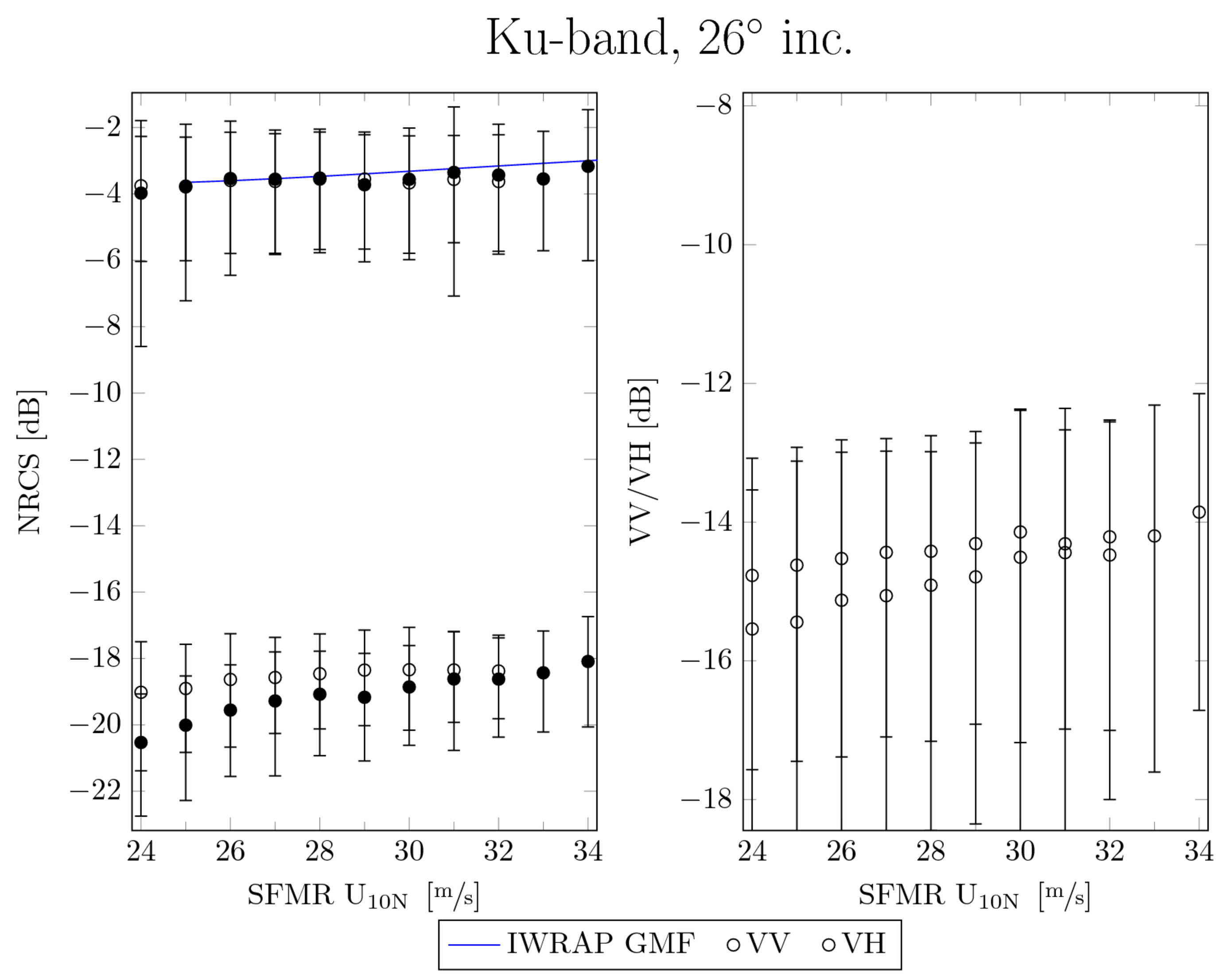


Figure 1: Left: Ku-band VV (upper pts.) and VH (lower pts.) NRCS averages at 26 degrees incidence angle vs. SFMR wind speed from 28 Sep 2011 (solid) and 5 Feb 2012 (open). Right: Polarization ratio (VH/VV) vs. SFMR wind speed. Differences in SFMR wind speed retrieval algorithms between flights may contribute to the observed difference between dates.

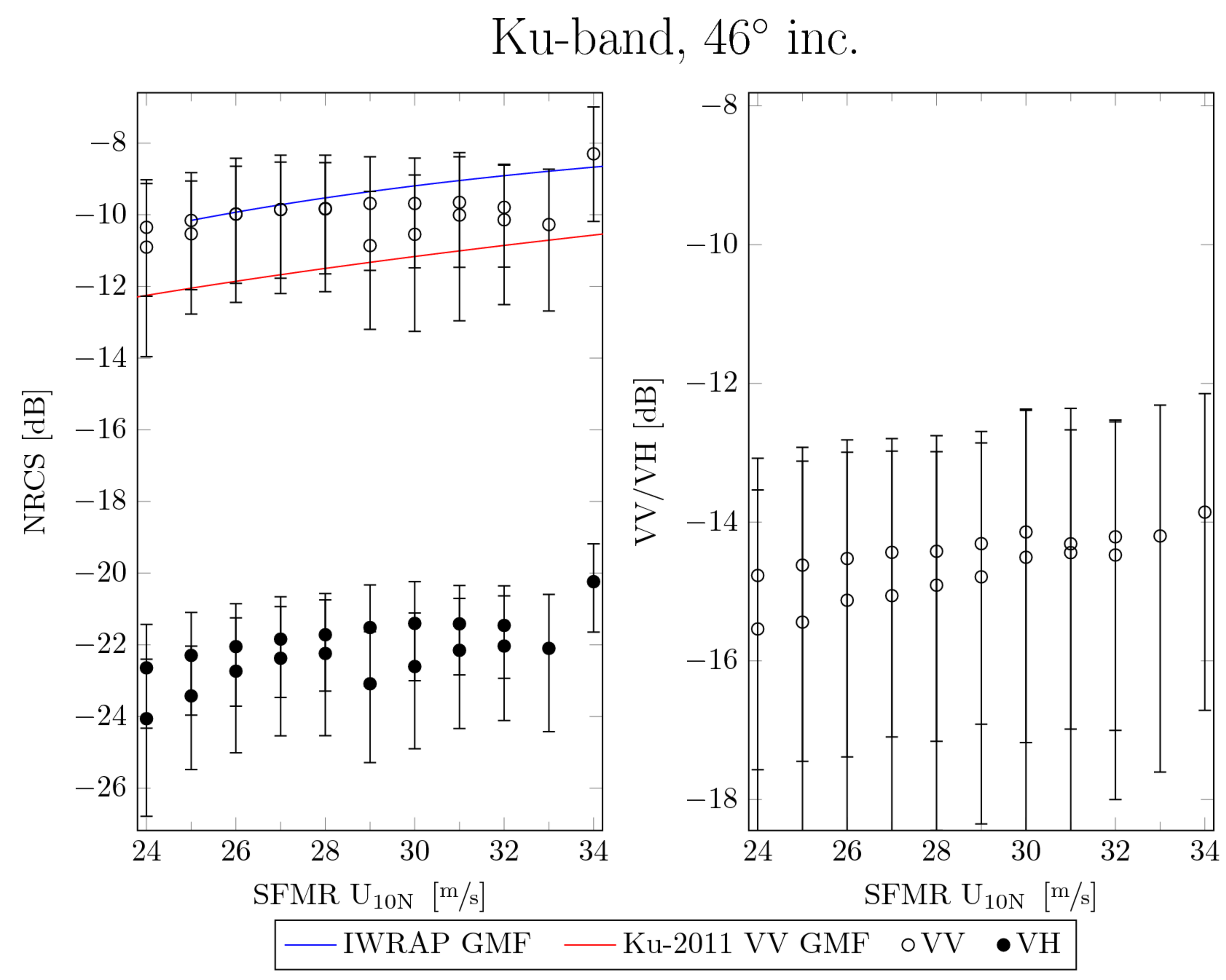


Figure 2: As in Figure 1, for Ku-band at 46 degrees incidence angle. The observed cross-polarized echo signal level is approximately equal to the result at 26 degrees incidence, indicating independence with incidence angle.

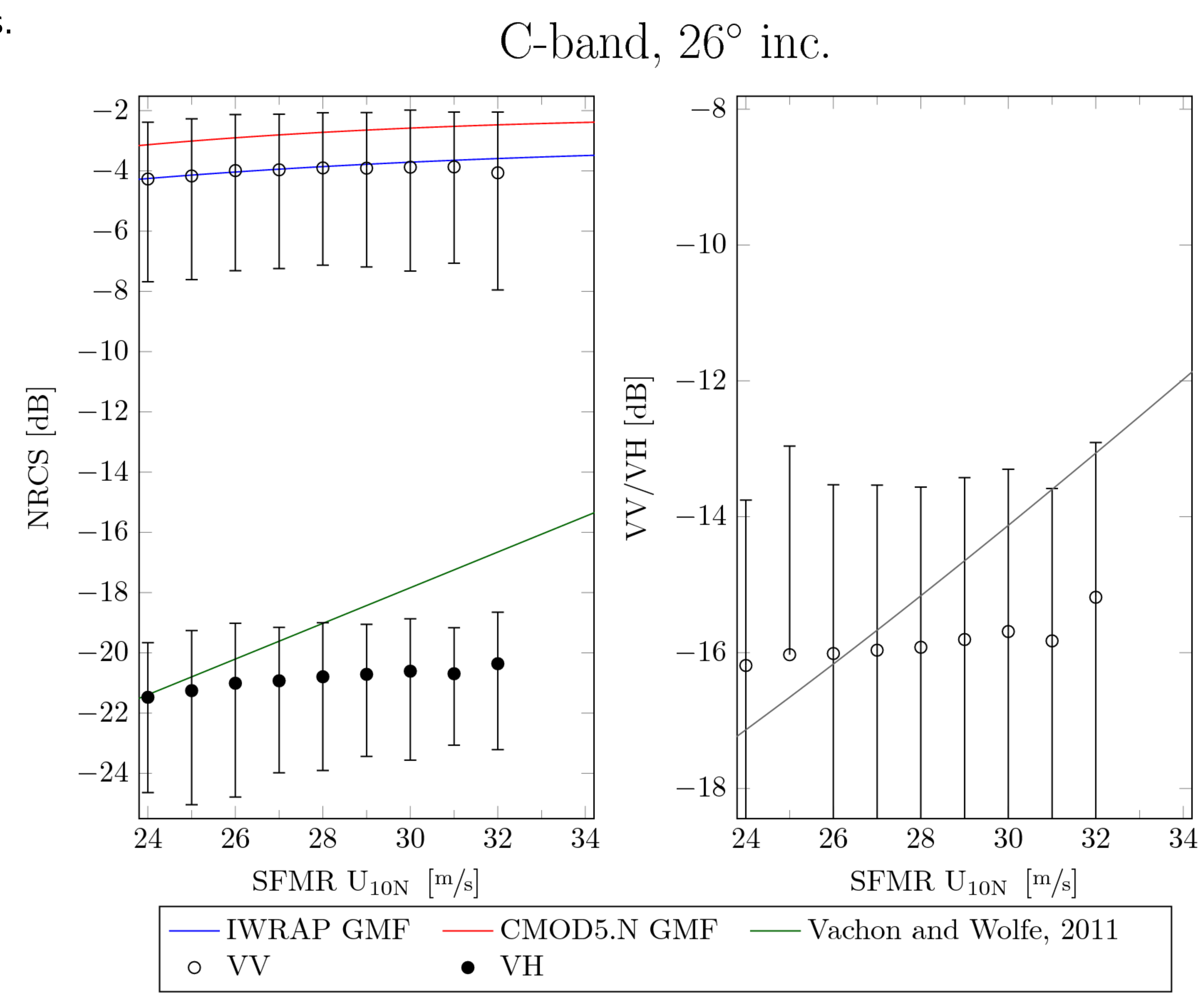


Figure 3: Left: C-band VV (open circles) and VH (solid circles) NRCS averages at 26 degrees incidence angle vs. SFMR wind speed from 5 Feb 2012. Green line denotes the VH model of Vachon and Wolfe (left) extrapolated for wind speeds >25 m/s. Right: Polarization ratio. Gray line denotes the ratio of the extrapolated Vachon and Wolfe model and the IWRAP GMF.

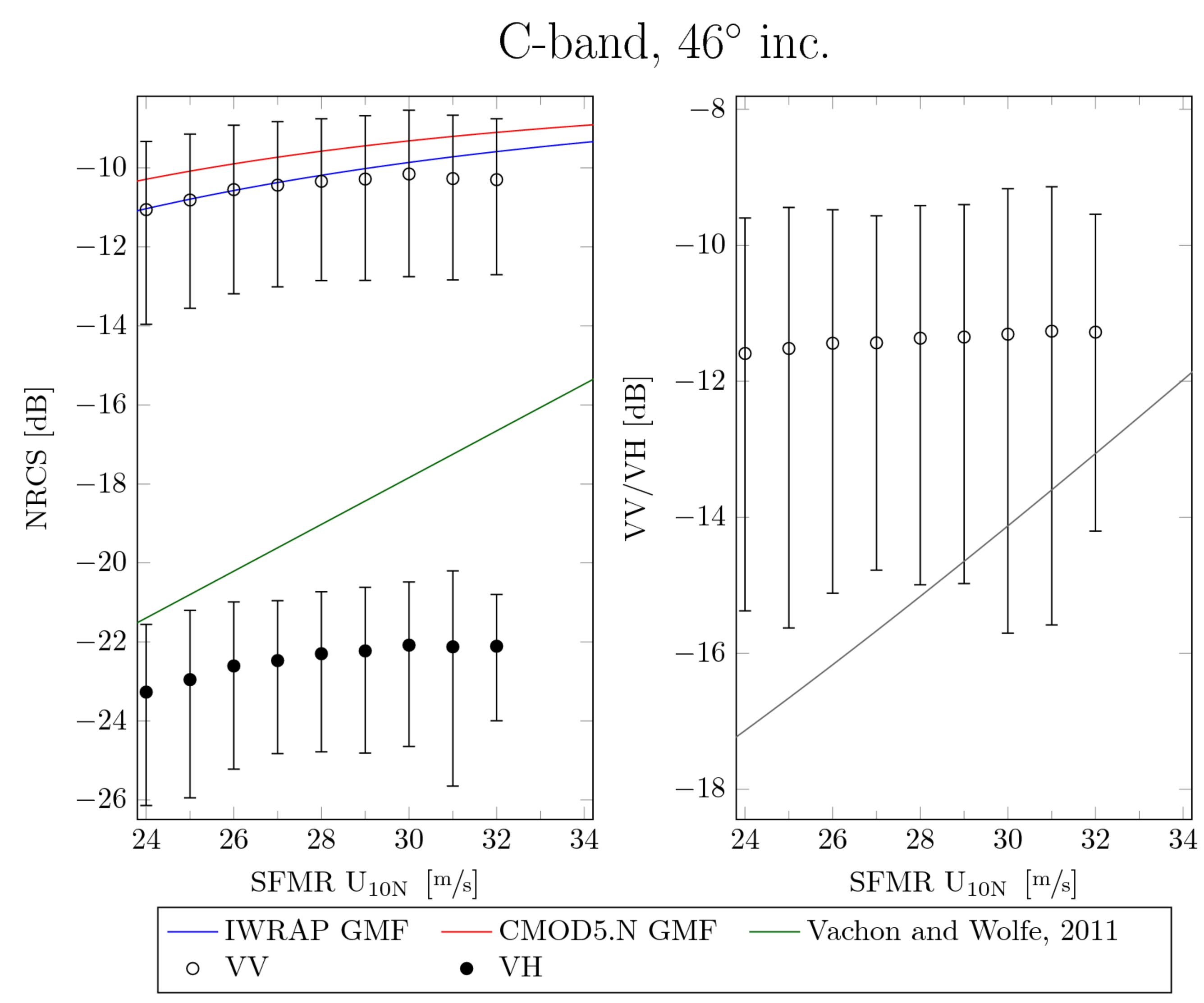


Figure 4: As in Figure 3, for C-band 46 degrees incidence. The cross polarized echo signal is approximately equal to that at 26 degrees incidence (though both are near the receiver noise level, which has been subtracted). Again, a lesser dependence with wind speed is observed compared to extrapolated results of Vachon & Wolfe.