Cross-Polarized C-band Scatterometer Measurements of the Sea Surface in Moderate Winds

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Experiment Overview
The Imaging Wind and Rain Airborne Profiler (IWRAP)

- Operated from a NOAA WP-3D “Hurricane Hunter” aircraft
- Developed and maintained by the University of Massachusetts Amherst’s (UMass) Microwave Remote Sensing Laboratory (MIRSL)
- Capable of measuring the sea-surface NRCS at all polarization combinations (VV, HH, VH, and HV)
The IWRAP C-band radar was configured to use a dual-polarized fan-beam antenna developed by RUAG for ESA for the next-generation European scatterometer.

Antenna is a dual-pol fan-beam antenna with cross-pol isolation > 40dB.

Antenna was mounted in a fixed position with bore sight at nadir.
Winter 2015 Experiment Design

- To sample in azimuth, aircraft performed 360° orbits at fixed roll angles up to 60°
- IWRAP operation was limited to 2 polarization configurations at a time (e.g., VV/VH), so multiple orbits were usually performed back-to-back to sample all polarizations at C-band
- Continuous circle patterns performed:
  - VV and VH: 71
  - HH and HV: 79
- Ku-band operated normally (VV/HH)
Cross-Polarized Sea-Surface NRCS Measurements
Data Analysis

- Calibration performed at 40° incidence for VV polarization using CMOD5.n model
  - Calibration resulted in a global offset of about -0.5 dB, which was then applied to all NRCS
- For each polarization:
  - NRCS and flight data were grouped into continuous orbits of at least 360°
  - NRCS were grouped in 1° incidence angle bins and 5.625° azimuth bins
- Surface wind information from buoys, dropsondes and GDAS model
  - To sample the surface wind vector, orbits were positioned near buoys or GPS dropsondes
  - Regions of consistent wind and no rain were targeted
Co-Pol NRCS ($A_0$) vs. Incidence Angle

van Z. 2014 ECMWF
CMOD5.n
HV
VH
HH
VV
Co-Pol and Cross-Pol
NRCS ($A_0$) vs. Incidence Angle

8 – 10 m s$^{-1}$

10 – 12 m s$^{-1}$

12 – 14 m s$^{-1}$

14 – 16 m s$^{-1}$

16 – 18 m s$^{-1}$

18 – 20 m s$^{-1}$

20 – 22 m s$^{-1}$

22 – 24 m s$^{-1}$

26 – 28 m s$^{-1}$

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van Z. 2014 ECMWF
CMOD5.n
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HH
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\[16 - 18 \text{ m s}^{-1}\]

\[18 - 20 \text{ m s}^{-1}\]

\[20 - 22 \text{ m s}^{-1}\]

\[22 - 24 \text{ m s}^{-1}\]

\[26 - 28 \text{ m s}^{-1}\]
Mean NRCS ($A_0$) vs. Wind Speed (VH)

- $25^\circ - 29^\circ$
- $30^\circ - 34^\circ$
- $35^\circ - 39^\circ$
- $40^\circ - 44^\circ$
- $45^\circ - 49^\circ$
- $50^\circ - 54^\circ$
- $55^\circ - 59^\circ$
- $60^\circ - 64^\circ$
- $65^\circ - 69^\circ$

Legend:
- Blue: van Z. 2014 SFMR
- Red: van Z. 2014 ECMWF
- Green: $\theta + 4$
- Orange: $\theta + 3$
- Yellow: $\theta + 2$
- Black: $\theta + 1$
- Brown: $\theta$

Graphs show the relationship between wind speed and mean NRCS ($A_0$) for different wind direction ranges.
Mean NRCS ($A_0$) vs. Wind Speed (VH)
NRCS vs. Relative Azimuth (VH)

- 8 – 10 m/s; 40.0°
- 10 – 12 m/s; 40.0°
- 12 – 14 m/s; 40.0°
- 14 – 16 m/s; 40.0°
- 16 – 18 m/s; 40.0°
- 18 – 20 m/s; 40.0°
- 20 – 22 m/s; 40.0°
- 22 – 24 m/s; 40.0°
- 26 – 28 m/s; 40.0°
Summary

- Observed VV NRCS matches well with CMOD5.n
- No differences in magnitude between VH and HV NRCS signals were observed
- Cross-pol dependence with incidence angle at all measured wind speeds
  - Dependence is higher in magnitude and slope than that modeled by van Zadelhoff et al., 2014
- Measured cross-pol NRCS wind speed dependence agrees with van Zadelhoff et al., 2014 SFMR-based model for incidence angles between 45° and 60°
  - Lower incidence angle measurements seem to follow the model shape but not magnitude
  - Measurements at higher wind speeds are needed to validate model trends
- Measured cross-pol NRCS exhibits a weak azimuthal modulation at wind speeds up to approximately 20m/s