Verification of the Origins of Rotation in Tornadoes EXperiment-Southeast (VORTEX-SE) ARMOR Radar Data Set Summary

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1.0 Data Set Overview:

1.1 Introduction

The University of Alabama in Huntsville (UAH) conducted VORTEX-SE operations on nine days between 25 March 2017 and 1 May 2017. Additional data collected prior to the start of the VORTEX-SE project have also been added. One of the radars used in support of operations for VORTEX-SE, and the platform outlined in this document, was the Advanced Radar for Meteorological and Operational Research (ARMOR).

1.2 Time period covered by the data

The data was collected from 10 March 2017 to 1 May 2017. Table 1 outlines ARMOR operations. The first entry consists of data collected from a shakedown operation.

Table 1 - Operation days.

Date	IOP #	Operations period
10 March 2017	UFO	0030 UTC to 0824 UTC
25 March 2017	IOP1a	1345 UTC to 2140 UTC
27-28 March 2017	IOP1b	1329 UTC to 0403 UTC
30-31 March 2017	IOP2	2030 UTC to 0159 UTC
3 April 2017	IOP3a	1900 UTC to 2200 UTC
5-6 April 2017	IOP3b	1110 UTC to 0050 UTC
22-23 April 2017	IOP3.5b	1937 UTC to 0045 UTC
27 April 2017	IOP4a	0156 UTC to 0736 UTC
28 April 2017	IOP4b	1555 UTC to 2355 UTC
30 April – 1 May 2017	IOP4c	1535 UTC to 0335 UTC

1.3 Physical location

ARMOR is located at the Huntsville International Airport. Its physical location is 34^{o} 38' 45.5 N 86^{o} 46' 16.7 W, 200m MSL.

1.4 Any web address references

Additional information about ARMOR can be found at http://armor.nsstc.uah.edu/about.php

2.0 Instrument Description:

ARMOR is a decommissioned National Weather Service local warning radar (WSR-74C) that was donated to UAHuntsville in 2002. This radar is located at the Huntsville International Airport and transmits at a frequency of 5625 MHz (C-band) with a 1^0 beam width. The full specifications for the radar can be found on Table 2. The radar was converted from single to dual-polarization in 2004 through a collaborative effort between UAH, NASA, and Huntsville's local news broadcaster WHNT channel 19.

The contributions from these partners also led to a series of hardware and software upgrades to the ARMOR radar from 2005-2006 that yielded a research-quality radar facility. The details of the upgraded radar components can be found in Petersen et al. (2009). ARMOR user control and data transmission are accomplished though a T1 line from the airport to UAH and its partners. The radar is operated by a combination of researchers and graduate students in both classroom and research environments and real-time data are provided to the Huntsville Alabama office of the National Weather Service and a local television news partner (Petersen et al. 2009).

2.1 Domain

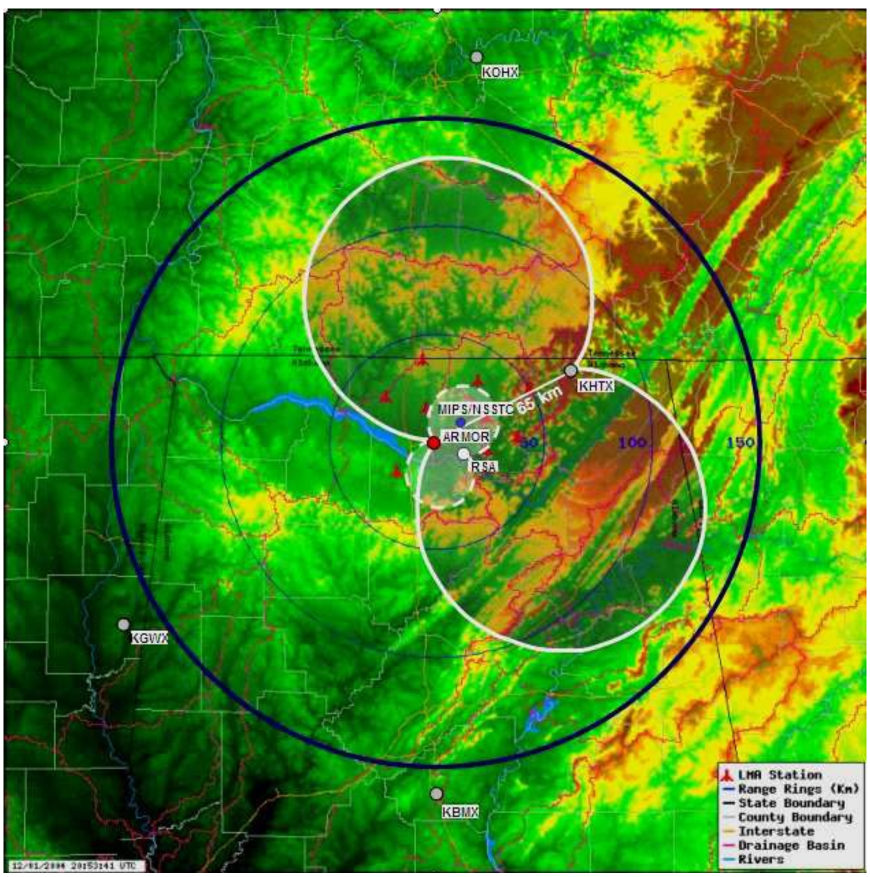

Figure 1 - ARMOR domain with dual-doppler lobes for KTHX.

The ARMOR domain is highlighted in Figure 1. This figure includes the dual Doppler lobes with the National Weather Service's Hytop radar. The baseline between ARMOR and the Hytop radar is 70 km.

2.2 Table of specifications

Table 2 - Table of specifications for ARMOR.

Location	Huntsville International Airport : 34° 38' 45.5 N 86° 46' 16.7 W
Altitude (antenna MSL)	200 m
Transmit frequency	5625 MHz
Peak Power	350 kW
Pulse width	0.4 – 2.0 μs
Maximum PRF	250-2000 s^{-1}
Antenna Diameter	3.7 m (12 ft CF Parabolic)
Antenna Beam width	1.1°
First side-lobe	-30 dB
Maximum/typical rotation rate	24° s-1 (18-21° s-1)
Transmit polarization	Simultaneous H and V, or H
Receive polarization	Dual-channel; H and V
Signal Process	SIGMET RVP/8
Variables	Z, V, W, ZDR, Φ_{DP}, KDP, ρ_{hv}, LDR

3.0 Data Collection and Processing:

3.1 Description of data collection

Data was collected 24 hours a day for the entirety of the field campaign. When not manned by radar operators, ARMOR continuously ran a combination of a three angle scan strategy (0.7, 1.3, and 2.0 degrees elevation to a range of 125 km) and a one angle surveillance strategy (0.7 degrees elevation to a range of 180 km). When ARMOR was manned by an operator during a weather event, a combination of full volume scans, sector scans, vertical scans over a single azimuth (RHIs), as well as the two scan strategies highlighted above were coordinated with other deployed radar assets and implemented. VORTEX-SE operations scan strategies are provided in Table 3. The main goal of the radar operator during this operation was to either a) cover the entire horizontal and vertical extent of the precipitation, including the anvil, as quickly and thoroughly as possible or b) rapidly sample evolution of low-level rotation.

3.2 Description of derived parameters and processing techniques used

The ARMOR C-band horizontal reflectivity (Z_H) and differential reflectivity (Z_{DR}) radar data were corrected for attenuation and differential attenuation effects using the differential phase-based, self-consistent method with constraints (Bringi et al. 2001). The differential propagation phase (ϕ_{DP}) was estimated and the specific differential phase (K_{DP}) was computed using the iterative filtering approach of Hubbert and Bringi (1995).

Table 3 - Table of ARMOR scan strategy options during active (i.e., manned) VORTEX-SE operations.

Name	Approx. Run Time	Scan Mode	Description	Pulse Duration (µs)	PRF (Hz)	R_{max} (km)	V_{max} (m s^{-1})	Elevation Angle Sequence	Angle Res. (°)	Doppler filter level	Rot. Rate (° s^{-1})	Bin Space (m)
RHI-1	1:01	RHI	Two RHIs at two azimuths	0.8	1200	124.9	16.1	0.2° to 30° elevation	0.3	3	2.8	125
RHI-2	0:52	RHI	One RHI at two azimuths	0.8	1200	124.9	16.1	0.2° to 45° elevation	0.3	3	2.8	125
FV-conv	2:48	360° PPI	Deep convective full volume	0.8	1200	124.9	16.1	0.7°, 1.8°, 2.8°, 4.3°, 6.3°, 8.8°, 11.8°, 14.8°, 17.8°, 20.8°	1	3	24.0	125
SV-conv-1	2:56	180° PPI	Deep convective sector volume	0.8	1200	124.9	16.1	0.7°, 0.9°, 1.3°, 1.8°, 2.7°, 3.9°, 5.7°, 7.7°, 9.5°, 11.5°, 13.4°, 15.0°, 17.5°, 19.5°, 21.3°	1	3	24.0	125
SV-conv-2	2:56	120° PPI	Deep convective sector volume	0.8	1200	124.9	16.1	0.7°, 0.9°, 1.3°, 1.8°, 2.7°, 3.9°, 5.7°, 7.7°, 9.5°, 11.5°, 13.4°, 15.0°, 17.5°, 19.5°, 21.3°, 24.2°, 26.0°	1	3	24.0	125
FV-meso	1:30	360° PPI	Miso/meso full volume	0.8	1200	124.9	16.1	0.7°, 1.5°, 2.3°, 3.1°, 4.6°	1	3	24.0	125
SV-meso-1	1:29	180° PPI	Miso/meso sector	0.8	1200	124.9	16.1	0.7°, 1.5°, 2.3°, 3.1°, 4.6°, 6.1°, 7.6°	1	3	24.0	125
SV-meso-2	1:30	120° PPI	Miso/meso sector volume	0.8	1200	124.9	16.1	0.7°, 1.5°, 2.3°, 3.1°, 4.6°, 6.1°, 7.6°, 9.1°, 10.6°	1	3	24.0	125
FV-clear	3:51	360° PPI	Clear air, boundary layer	1.0	1000	149.9	13.4	0.7°, 1.5°, 2.2°, 3.0°, 3.8°, 4.6°, 5.4°, 6.2°, 7.0°, 8.5°, 10.0°	1	2	20.0	150
FV-clutter	4:31	360° PPI	Clutter map	0.8	1200	124.9	16.1	0.7°, 1.5°, 2.3°, 3.1°, 3.8°, 4.5°, 5.2°, 5.9°	1	0	12.0	125

3.3 Description of quality assurance and control procedures

Receiver calibration is typically performed regularly as one of ARMOR's quality assurance procedures. However, as of 6 February 2017, the switch controlling the polarization of transmitted and received signal was reported to have failed. Without the ability to switch to either horizontal- or vertical-only polarization, calibration of the receiver was not possible. Users should note that absolute calibration of the provided data should be assessed (e.g., according to techniques discussed in Ryzhkov et al. (2005)).

Vertically pointing Z_{DR} calibration scans (Gorgucci et al. 1999) were conducted before the VORTEX-SE field campaign. More specifically, Z_{DR} calibration is performed as often as weather permits and was performed following substantial radar repairs in anticipation of VORTEX-SE operations. The existing GDR was changed on 1 March 2017 after a series of calibrations scans and subjective data assessment to an offset of -1.38 dB.

The raw data have been provided, as well as processed data converted to Universal Format (UF) with propagation correction according to Bringi et al. (2001).

4.0 Data Format:

4.1 Data file structure and file naming conventions

The ARMOR data set delivered to the VORTEX-SE Data Archive is in the Raw and Universal Format. An example of the RAW ARMOR file naming convention is as follows:

RAW_NA_000_125_20160314081927.gz

where RAW indicates the file format, 125 indicates the scan type (in this case full volume PPI, RHIs and sector volumes were also performed), 20160314 indicates the date (YYYYMMDD), and 081927 indicates the time in UTC (HHMMSS).

An example of the quality controlled UF ARMOR file naming convention is as follows:

ARMOR_20160314081927_qc1.uf.gz

where ARMOR indicates the radar, "20160314" indicates the date (YYYYMMDD), "081927" indicates the time in UTC (HHMMSS), "qc1" indicates ARMOR processed data, and "uf" indicates the file format.

4.2 List of parameters with units

Table 4 - Table of ARMOR parameters.

Identifier	Units	Definition
CD	dB	Corrected differential reflectivity (Z_{DR}); corrected for differential attenuation
CZ	dBZ	Corrected horizontal reflectivity (Z_H); corrected for attenuation
DR	dB	Differential reflectivity (Z_{DR}) (Uncorrected for propagation effects)
DZ	dBZ	Horizontal reflectivity (Z_H) (Uncorrected for propagation effects)
KD	$°\ km^{-1}$	Specific differential phase (K_{DP})
MZ	°	Differential Phase (ψ_{DP}) (measured)
PH	°	Differential propagation phase (ϕ_{DP}) (filtered)
RH	Unitless	Co-polar correlation coefficient (between H- and V- polarization)
SW	$m\ s^{-1}$	Spectral width (σ)
VR	$m\ s^{-1}$	Radial (or Doppler) velocity (V_R)

4.3 Data version number and date

This document describes the preliminary VORTEX-SE ARMOR data delivery (August 2017).

5.0 Data Remarks:

5.1 PI's assessment of the data (i.e., disclaimers, instrument problems, quality issues, etc.)

Propagation effects have been corrected in ARMOR reflectivity and differential reflectivity using well-tested procedures described in Bringi et al. (2001). However, some artifacts associated with propagation effects can remain or even be inadvertently generated during the correction process. We continue to assess the quality of the propagation correction during VORTEX-SE but have high confidence in the general results as we have been using the algorithms regularly during research for over 9 years. Because of the inability to conduct regular receiver calibrations with ARMOR during 2017, we recommend that users who are interested in quantitative applications with horizontal reflectivity consider using polarimetric consistency to obtain a calibration accuracy with 1-2 dB (e.g., Ryzhkov et al. 2005). Radial (Doppler) velocity data is still folded at the Nyquist interval (Table 3; 13.4 $m\ s^{-1}$ or 16.1 $m\ s^{-1}$). Unfolding of the radial velocity data is ongoing for multi-Doppler synthesis. Unfolded data for specific case studies will be provided for specific case study periods at the final data delivery.

5.2 Missing data periods

The ARMOR radar ran continuously during the VORTEX-SE field campaign, including intensive observation periods listed in Table 1. Known exceptions are discussed in the ARMOR daily summaries and science logs on the VORTEX-SE Field Catalog.

5.3 Software compatibility (i.e., list of existing software to view/manipulate the data)

ARMOR data can be converted in NCAR Dorade sweep (swp) format (Dixon, 2010) to be viewed and manipulated with the NCAR soloiii radar software package found at http://www.eol.ucar.edu/Members/dennisf/soloii-and-xltrsii/getting-soloii-and-xltrsii and described at http://www.eol.ucar.edu/rdp/solo/solo_home.html .

6.0 References:

Advanced Radar for Meteorological and Operational Research. http://armor.nsstc.uah.edu/about.php

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