Verification of the Origins of Rotation in Tornadoes EXperiment-Southeast (VORTEX-SE) MAX 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 seven days between March 13th and May 01st 2016. 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 Mobile Alabama X-band (MAX) radar.

1.2 Time period covered by the data

The data was collected from February 24th 2016 to May 1st 2016. Table 1 outlines each operation day, including other instruments used. The first two dates consist of data collected from a pre-VORTEX-SE and a shakedown operation. In this table, Advanced Radar for Meteorological and Operational Research (ARMOR), MAX is the Mobile Alabama X-band Radar, KHTX is the Hytop WSR88D dual-polarimetric radar, NALMA is NASA MSFC's Northern Alabama Lightning Mapping Array.

Date	IOP #	Ground Instruments
2/24/2016	IOP_0_0	ARMOR-KHTX, NALMA
3/1/2016	IOP_0_1	ARMOR-MAX-KHTX, NALMA
3/13/2016-3/14/2016	IOP_1	ARMOR-MAX-KHTX, NALMA
3/24/2016	IOP_2	ARMOR-MAX-KHTX, NALMA
3/31/2016-4/1/2016	IOP_3	ARMOX-MAX-KHTX, NALMA
4/27/2016-4/28/2016	IOP_4	ARMOR-MAX-KHTX, NALMA
4/29/2016-4/30/2016	IOP_5	ARMOR-MAX-KHTX, NALMA
4/30/2016	IOP_6	ARMOR-MAX-KHTX, NALMA
5/1/2016	IOP_7	ARMOR-MAX-KHTX, NALMA

Table 1 - Operation days including all platforms in use.

As shown in Table 1, the MAX radar was deployed on 7 VORTEX-SE operational missions (3/13-3/14, 3/24, 3/31-4/1, 4/27-4/28, 4/29-4/30, 4/30 and 5/1), with an additional deployment for a shakedown operation (3/1). More details on these specific events can be found in the VORTEX-Se Field Catalog (FC) - http://catalog.eol.ucar.edu/vortex-se_2016.

1.3 Physical location

During VORTEX-SE, the MAX radar was deployed to four different locations during operations. These locations consisted of the Grove Oak, AL (3/1), Rogersville, AL (3/13-3/14), Courtland Airport, AL (3/24, 3/31-4/1, 4/27-4/28 and 4/29-4/30), and Tanner, AL (4/30 and 5/1). Table 2 outlines the deployment sites MAX was located with elevation.

Location	Coordinates	Elevation
Grove Oak, AL	34°25'8.76"N and 86°1'34.68"W	357 m

Rogersville, AL	34°51'1.07"N and 87°20'17.64"W	203 m
Courtland, AL	34°39'18.252"N and 87°20'53.5914"W	178 m
Tanner, AL	34°43'50.8434"N and 86°56'14.6754"W	200 m

Table 2 – MAX deployment sites.

1.4 Any web address references

Additional information about MAX can be found at http://vortex.nsstc.uah.edu/mips/max/

2.0 Instrument Description:

MAX is an X-band, dual-polarimetric truck-based mobile radar. The MAX truck cab has room for a 2-3 person team who will similarly accomplish radar control via IRIS display, communications (via Internet chat on cell phone modem), and Nowcasting duties. Like most truck-based mobile radars, MAX's view of storms is obscured in the direction of the truck cab (i.e., "cab block"). MAX's cab block is about 30°-40° in azimuthal width and is up to 10° in elevation. During VORTEX-SE multi-Doppler operations, MAX was deployed from its home base at NSSTC to four different radar locations. These locations varied in beam blocking and other site issues, which can be found in the VORTEX-SE FC. The direction of the MAX truck cab can also be found in the daily summaries in the VORTEX-SE FC.

2.1 Domain

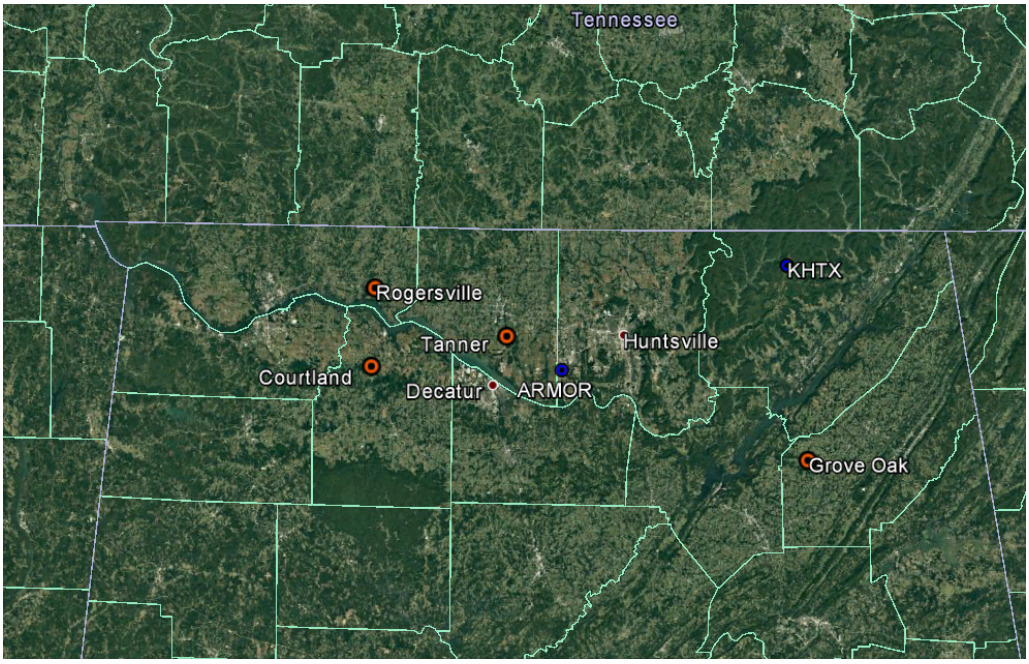

Figure 1 – VORTEX-SE MAX radar locations, including MAX radar, ARMOR and WSR88D Hytop radar. MAX deployment sites are marked as orange circles.

The MAX domain (marked with orange circles) is highlighted in Figure 1.

2.2 Table of specifications

Location	Near New Market, AL : 34°55'56.23"N and 86°27'57.01"W
Transmit frequency	9450 MHz (magnetron)
Peak Power	250 kW
Pulse width	0.4, 0.8, 1.0, 2.0 μs
Maximum PRF	250-2000 s^{-1}
Antenna Diameter	2.44 m (Center-fed parabolic)
Antenna Beam width	0.95^{o}
First side-lobe	-31 dB
Maximum 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, σ, ZDR, ϕ_{DP}, KDP, ρ_{hv}, LDR

Table 2 - Table of specifications for MAX.

3.0 Data Collection and Processing:

3.1 Description of data collection

When MAX deployed during a weather event, a combination of full Plan Position Indicator (PPI) volume scans, PPI sector volume scans, and vertical scans over a single azimuth (or Range Height Indicators, RHIs) were implemented. Sector scans were coordinated with the UMASS X-Pol mobile radar and ARMOR to focus on a storm of interest. The main goal of the radar operator during MAX scanning was to cover the entire horizontal and vertical extent of the precipitation, including the anvil, as quickly and thoroughly as possible. More details regarding the scan strategy can be found in the VORTEX-SE Operations Plan.

3.2 Description of quality assurance and control procedures

Vertically pointing ZDR calibrations scans were performed as often as operations permitted and precipitation echo was present overhead (Gorgucci et al. 1999).

Since it is a truck-based mobile system, the MAX radar azimuth data have been corrected for any deviations to true north. A GPS system was used in the field to identify the MAX azimuth relative to true north and adjust MAX heading accordingly. These preliminary field corrections to MAX azimuth angles are being verified and fine-tuned in post-processing during and after the intensive observational period using well characterized nearby stationary ground targets and comparison of other radars such as KHTX or ARMOR. A sector shift problem is also identified in the MAX IRIS data in some PPI sector volumes. These shifts will be corrected in MAX data in the same fashion as described for ARMOR. Essentially, the azimuthal angles (locations) of MAX radar data for every other PPI in a PPI sector volume were shifted from their true heading during raw data recording in the RCP8. These shifted PPI's will be identified and corrected with a combination of automated scripts and careful manual analysis. Well characterized ground targets and comparison to adjacent MAX 360° surveillance scans or other radar displays were used to identify and verify the MAX azimuth angle corrections.

The raw data have been provided, as well as data converted to Universal Format (UF) for processing.

4.0 Data Format:

4.1 Data file structure and file naming conventions

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

RAW_NA_000_120_20160401002955.gz

where RAW indicates the file format, 120 indicates the scan type (in this case full volume PPI, RHIs and sector volumes were also performed), 20160401 indicates the date (YYYYMMDD), and 002955 indicates the time in UTC (HHMMSS).

An example of the Universal Format file naming convection is as follows:

MAX160314052733.RAWW5D9.gz

where MAX indicates the radar name, 160314 indicates the date (YYMMDD), 052733 indicates the time in UTC (HHMMSS), and RAWW5D9 indicates the conversion of RAW data to UF.

4.2 List of parameters with units

Identifier	Units	Definition
ZDR	dB	Differential reflectivity (Z_{DR}) (Uncorrected for propagation effects)
DBZ	dBZ	Horizontal reflectivity (Z_H) (Uncorrected for propagation effects)
KDP	° km^{-1}	Specific differential phase (K_{DP})
PHIDP	°	Differential propagation phase (ϕ_{DP}) (filtered)
RHOHV	Unitless	Co-polar correlation coefficient (between H- and V- polarization)
WIDTH	m s^{-1}	Spectral width (σ)
VEL	m s^{-1}	Radial (or Doppler) velocity (V_R)

Table 3 - Table of MAX parameters.

4.3 Data version number and date

This document describes the preliminary VORTEX-SE MAX data delivery (October 2016).

5.0 Data Remarks:

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

Propagation effects have not yet been corrected in MAX reflectivity and differential reflectivity data.

In the preliminary data, radial (Doppler) velocity data is still folded at the Nyquist interval (9.5 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.

The post-processing corrections of the azimuth angle associated with heading errors and some PPI sector shift problems are expected to be accurate to better than a couple tenths of a degree (< 0.2°). We continue to assess the accuracy of the azimuth angle post-processing corrections.

Spatial smearing of the MAX radar data, which appears as azimuthally or elevationally elongated range gate samples, sometimes occurred on the outer azimuthal edges of PPI tilts in some sector volumes or in the middle of RHI scans, respectively. The occasional spatial smearing in MAX data appears to be associated with occasional inappropriate scan speeds and accelerations due to occasional MAX antenna motor control problems during VORTEX-SE, as noted during daily briefings and in the MAX daily summaries and science logs. The spatial smearing is only occasional and is fairly easy to identify and remove manually. We will continue to remove smearing on the edge of PPI sector volumes, but some spatial smearing may remain in a few PPI's and RHI's for final data delivery.

5.2 Missing data periods

When deployed for VORTEX-SE (Table 1), the MAX radar was operation for all periods except during the pre-VORTEX-SE operation. A few known exceptions when the MAX radar went down during VORTEX-SE operations are discussed in the MAX 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)

MAX 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:

Dixon, 2010: Radx C++ Software Package for Radial Radar Data. http://www.ral.ucar.edu/projects/titan/docs/radial_formats/radx.html

Gorgucci, E., G. Scarchilli, and V. Chandrasekar, 1999: A procedure to calibrate multiparameter weather radar using properties of the rain medium. *IEEE Trans. Remote Sens.*, **37**, 269-276.

Mobile Alabama X-band Dual Polarization Radar. http://vortex.nsstc.uah.edu/mips/max/