Deep Convective Clouds and Chemistry (DC3) 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 radar operations on twelve days between May 15 and June 15 2012. One of the radars used in support of operations for DC3, 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 May 15th 2012 to June 15th 2012. Table 1 outlines each operation day, including other instruments used. In this table, 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, and MIPS is UAH's Mobile Integrated Profiling Systems.

Date	Ground Instruments
5/15/2012	ARMOR-KHTX, NALMA, 1 sonde
5/18/2012	ARMOR-MAX-KHTX, NALMA, 2 sondes
5/19/2012	ARMOR-KHTX, NALMA
5/20/2012	ARMOR-KHTX, NALMA
5/21/2012	**ARMOX-MAX-KHTX, NALMA, 4 sondes, MIPS**
5/29/2012	ARMOR-MAX-KHTX, NALMA, 2 sondes
5/31/2012	ARMOR-MAX-KHTX, NALMA, MIPS deployed in DD lobes, 3 sondes
6/3/2012-6/4/2012	ARMOR-MAX-KHTX, NALMA, MIPS
6/4/2012-6/5/2012	ARMOR-MAX-KHTX, NALMA, MIPS deployed in DD lobes, 4 sondes
6/11/2012	**ARMOR-MAX-KHTX, NALMA, MIPS, 5 sondes**
6/14/2012	ARMOR-KHTX, NALMA, 1 sonde
6/15/2012	ARMOR-KHTX, NALMA, 1 sonde

Table 1 - Operation days including all platforms in use. Aircraft operation days in bold.

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

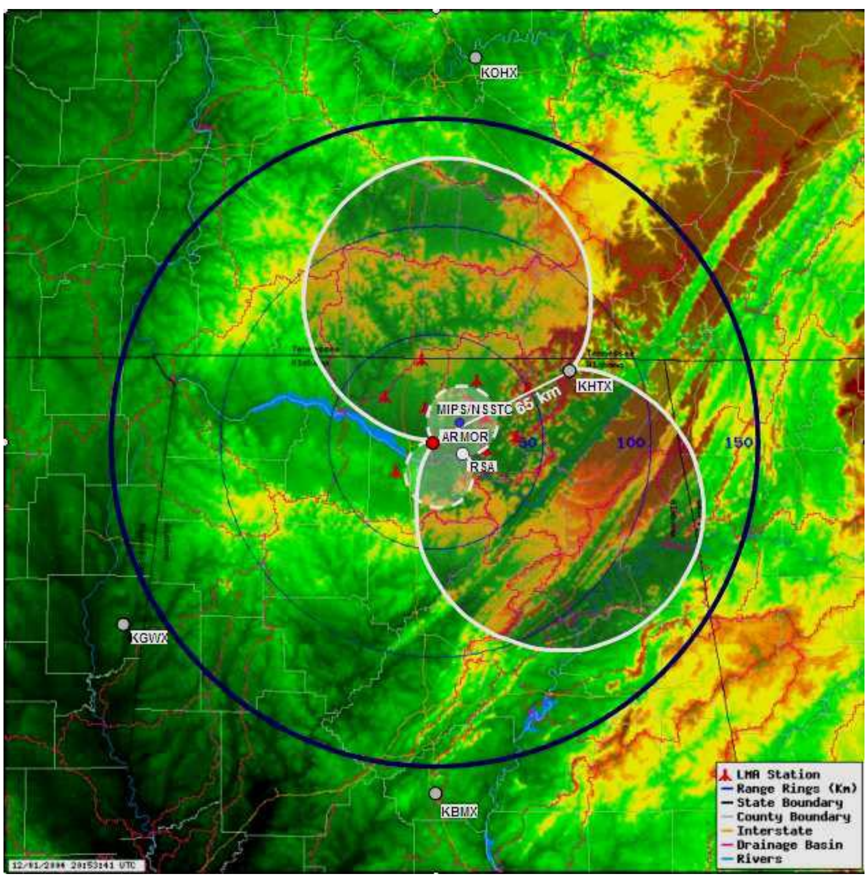

Figure 1 - ARMOR domain with dual-doppler lobes for KTHX.

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

2.2 Table of specifications

Location	Huntsville International Airport : 34^o 38' 45.5 N 86^o 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^o
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

Table 2 - Table of specifications for ARMOR.

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 to 125 km) and a one angle surveillance strategy (0.7 degrees to 180 km). When ARMOR was manned by 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 implemented. The main goal of the radar operator during this operation was to cover the entire horizontal and vertical extent of the precipitation, including the anvil, as quickly and thoroughly as possible. More details on scan strategy can be found in the DC3 Operations Plan.

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).

3.3 Description of quality assurance and control procedures

As one of ARMOR's quality assurance procedures, a receiver calibration is conducted every 2 weeks as weather permits. This calibration was performed on April 23rd 2012 in preparation for DC3, as well as May 12th 2012 and May 24th 2012 during the field program. A sun calibration was conducted on June 18th 2012 and resulted in a 0.01 degree offset in azimuth 0.02 degrees offset in elevation. These results show that the pointing angle error is within acceptable limits.

Vertically pointing Z_{DR} calibration scans (sometimes called "birdbath scans") (Gorgucci et al. 1999) were also conducted before, during, and after the DC3 field campaign. More specifically, Z_{DR} calibrations are performed as often as weather permits and this calibration was performed in anticipation of and during DC3 operations. The existing differential channel gain (GDR, RVP8 User's Manual 2005 p.B10-B-26) was changed on May 3rd 2012 to 0.38 dB since the Z_{DR} bias (0.44 dB) was above the noise threshold of 0.15 dB. This GDR is an offset value calculated when there is a difference between the gain at the two different polarizations, and this bias is larger than the noise threshold. The GDR value is added to the Z_{DR} otherwise computed and is stored to the nearest 1/16 of a dB (IRIS/RDA Utilities Manual 2008, p.6). The Z_{DR} bias for subsequent calibrations (conducted on May 9th 2012 and May 13th 2012) remained below the noise threshold (0.0889 dB and -0.079 dB). A final Z_{DR} calibration scan was conducted on July 11th 2012 to assess the system bias, yielding a value of +0.05 dB. In summary, ARMOR's ZDR calibration was stable throughout the field campaign and within ± 0.1 dB of 0 dB, which is unbiased within the expected accuracy of the method. The delivered data requires no further modification.

Once the data was gathered and stored, quality control procedures were followed to ensure the data delivered was of the highest quality possible. An azimuthal sector shift problem for some ARMOR PPI sector volumes was identified during the field campaign and was corrected in post-processing for the preliminary data delivery. Essentially, the azimuthal angles (locations) of 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 were identified and corrected with a combination of automated scripts and careful manual analysis. Well characterized ground targets and comparison to adjacent ARMOR 360° surveillance scans were used to identify and verify the ARMOR azimuth angle corrections. The data were converted to Universal Format (UF) for processing and to Dorade Sweep (swp) formats with the use of NCAR's Radx software (Dixon, 2010).

Day	Z_h Bias (dB)
5/18/2012	1.98
5/21/2012	0.89
6/3/2012-6/4/2012	0.74
6/5/2012	1.81
6/11/2012	0.16
Average	1.12

Table 3 - Z_h bias results for DC3 cases.

Finally, the issue of absolute calibration of radar reflectivity was addressed for final data delivery. The methodology outlined in Ryzhkov et al. 2005, which calibrates horizontal reflectivity (Z_h) based on differential phase measurements and polarimetric self-consistency, was used in five cases including the two aircraft cases (Table 3). The other six cases were not eligible for this type of calibration because of the widely scattered nature of the storms (and therefore unsatisfactory sample size), due to hail contamination, or a combination of the two. The case dates and calculated Z_h bias are offered in Table 3. These results indicate that the radar had a small positive (i.e., high) reflectivity bias that varied slightly during the field project (Average ± Standard Deviation = +1.1 dB ± 0.8 dB). Data users could make the decision to adjust the horizontal reflectivity according to these daily bias results, or use an average of the results for days that did not allow for a Z_h bias estimate. Alternatively, since the standard deviation of the estimated bias is less than the ± 1 dB accuracy of the self-consistency method, users could also subtract the mean bias of +1.1 dB from Z_h for all DC3 days. UAH has left it to the user to determine the best bias estimate for the given day of interest. Hence, the delivered horizontal reflectivity data has not yet been adjusted for estimated bias error.

4.0 Data Format

4.1 Data file structure and file naming conventions

The ARMOR data set delivered to the DC3 Data Archive is in the NCAR Dorade Sweep format. An example of the naming convention is as follows:

swp.1120605143038.ARMOR.0.0.7_PPI_v001

where swp indicates the file format, 120605 indicates the date (YYMMDD), 143038 indicates the time in UTC (HHMMSS), ARMOR is the radar name, 0.0.7 indicates the elevation angle (00.7 degrees), PPI indicates the scan type (in this case PPI, RHIs were also performed).

4.2 List of parameters with units

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)

Table 4 - Table of ARMOR parameters.

4.3 Data version number and date

This document describes the final DC3 ARMOR data delivery (July 2013).

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 DC3 but have high confidence in the general results as we have been using the algorithms regularly during research for over 5 years. Radial (Doppler) velocity data is still folded at the Nyquist interval (15.9 m s^{-1}). The post-processing correction of the azimuth angle associated with some PPI sector volumes (i.e., correction of the sector shift problem) is 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. A preliminary check on absolute and relative calibration has been accomplished and found to be stable based on available calibration scans and procedures (Section 3.3).

5.2 Missing data periods

The ARMOR radar ran continuously during the DC3 field campaign, including intensive observation periods listed in Table 1. Known exceptions are discussed in the ARMOR daily summaries and science logs on the DC3 Field Catalog.

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

ARMOR data in NCAR Dorade sweep (swp) format can be viewed and manipulated with the NCAR soloii 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

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