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12R.4 THE UAH-NSSTC/WHNT ARMOR C-BAND DUAL-POLARIMETRIC RADAR: A UNIQUE COLLABORATION IN RESEARCH, EDUCATION AND TECHNOLOGY TRANSFER

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1. INTRODUCTION

Figure 1. ARMOR radar at Huntsville International Airport.

The University of Alabama Huntsville/National Space Science and Technology Center (UAH/NSSTC) C-band WSR-74C Doppler radar (Fig. 1) was recently upgraded in a joint project between NSSTC and WHNT-TV to dual-polarimetric capability. The upgraded radar, named ARMOR (Advanced Radar for Meteorological and Operational Research), is located at Huntsville International Airport under the coverage umbrella of the NASA N. Alabama Lightning Mapping Array (LMA) and within the northern Alabama Severe Thunderstorm Observations and Research Meteorological network (STORMnet; Fig. 2).

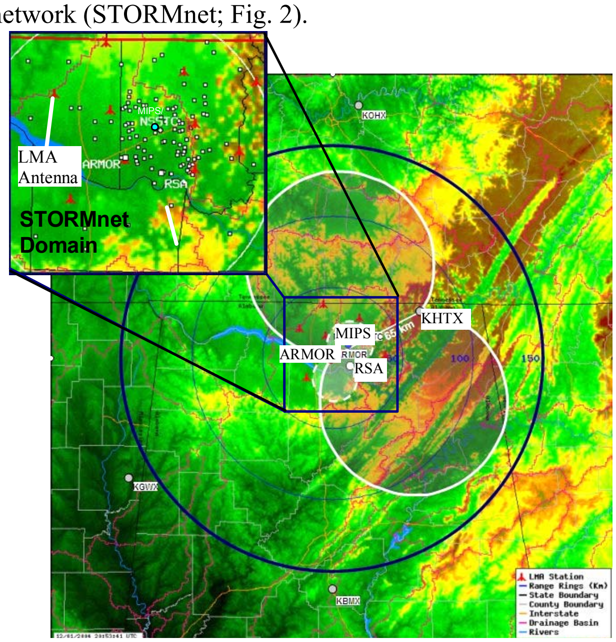

Figure 2. STORMnet: Location of ARMOR, KHTX and RSA Radars together with MIPS (nominally located at NSSTC), LMA antennas and CHARM rain guage sites (upper left).

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In addition to serving as an education and research tool at NSSTC/UAH, to the best of our knowledge, ARMOR is the only operational dual-polarimetric radar in the world to be used concurrently by broadcast meteorologists (WHNT-TV, Huntsville). The radar data and derived products are also provided to the Huntsville National Weather Service (NWS) Forecast Office in test mode for warning decision support and training purposes.

2. ARMOR SPECIFICATIONS, DATA AND OPERATIONS

Location :	Huntsville Intl. Airport
Transmit frequency:	5625 MHz
Peak Power:	350 kW
Pulse width:	0.4, 0.8, 1.2, 2.0 μs
Maximum PRF:	250-2000 s-1
Antenna Diameter	3.7 m (CF Parabolic)
Antenna Beam width:	1°
First side-lobe:	-23 dB
Maximum rotation rate:	18° s^{-1}
Transmit/RX polarization:	Simultaneous H and V, or H
Sig. Processor:	SIGMET RVP/8
Variables:	Z, V, W, ZDR, Φ_{DP}, KDP, ρ_{hv}, LDR

Major hardware upgrades to ARMOR include the SIGMET Antenna Mounted Receiver (AMR) with a dual-polarimetric option, a new 350 kW solid state transmitter (magnetron), RCP-8/RVP-8 radar controller and signal processor, AMR wave-guide assembly, a new dual-polarimetric feed and a new 18 ft. sandwich foam-core radome coated with a state of the art resilient hydrophobic paint. The existing WSR-74C 3.7 meter EEC antenna and pedestal (both in good condition) are currently being used for operations until funds can be secured to upgrade both pieces of hardware.

The AMR and wave-guide assembly are mounted on the back of the ARMOR antenna eliminating the need for dual-rotary joints and signal loss through long wave-guide runs to the receiver. Data from the AMR is transmitted through the pedestal via a power line LAN to a control and processing computer located in an adjacent building. In turn, the raw data are forwarded via a direct T-1 connection from the airport to NSSTC.

The AMR hardware/software enable both single linear polarization transmit, with co- and cross-pol receive, and simultaneous linear transmit and receive (STAR) modes. In both modes, the standard weather radar variables of total power (T), reflectivity (Z), radial velocity (VR) and spectral width (W) are collected. In STAR mode three additional dual- polarimetric variables are collected including: differential reflectivity (ZDR), differential propagation phase (Φ_{DP}), and the correlation coefficient (ρ_{hv},). In addition to Φ_{DP}, the RVP-8 automatically computes specific differential phase (KDP) using a linear least squares algorithm (cf. Bringi and Chandrasekar, 2001).

In parallel with the RVP8 processing, real-time dual-polarimetric data processing at NSSTC employs locally-modified software originally developed for the BMRC C-pol radar (developed by V. N. Bringi; CSU and shared by T. Keenan, BMRC) to compute differential back scatter phase and KDP using a FIR/adaptive spatial filter approach.. The software also corrects Z and ZDR for attenuation and differential attenuation respectively (e.g., Fig. 3), and then computes polarimetric estimates of rainfall.

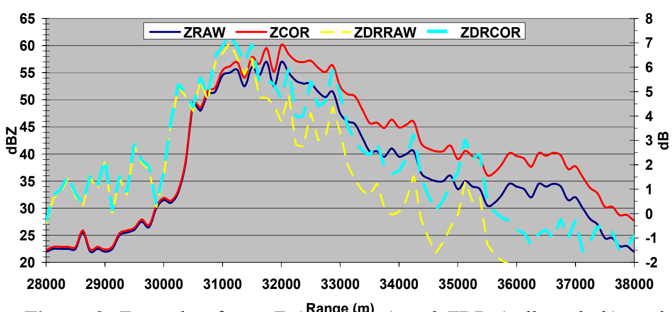

Figure 3. Example of raw Z (navy blue) and ZDR (yellow dash), and corrected Z (red) and ZDR (light blue dash) collected on 4/7/05 along a propagation path consisting of mixed large hail and rain.

Note that current ARMOR antenna side lobes are typically sufficient for collection of all variables except LDR; hence the radar is operated primarily in STAR mode for dual-polarimetric applications. Importantly, operation in STAR mode (64 sample pairs; 125 m gate spacing) enables more efficient scanning in rapidly evolving convective situations while facilitating collection of variables fundamental to advanced rainfall and hydrometeor identification (HID) algorithms (Z, ZDR, KDP, ρ_{hv}; Straka et al., 2000, Liu and Chandrasekar, 2000; Zrnic et al., 2001; Schuur et al., 2003; Ryzhkov et al., 2003; Baldini et al., 2005, this conference).

When not in STAR mode, surveillance (SUR) data collection in the single polarization mode is often used for high temporal resolution (single sweep, 0.8°) sampling of both clear air and convection. For research purposes, these scans are used for convective initiation and boundary layer studies (e.g., Fig. 4). WHNT-TV and WFO Huntsville also use the SUR data to fill time gaps when NEXRAD radar data are not available.

To satisfy both operational and research considerations ARMOR is operated 24 hours per day, seven days a week in either SUR (non-polarimetric), RAIN1 (polarimetric, rainfall/hydrology scan) or sector volume scans (polarimetric). Vertically pointing ZDR scans are collected on a target of opportunity basis to calibrate ZDR. Solar and receiver calibrations are conducted *at least* once a week. Radar control, display, data ingest, and archive are managed at NSSTC, with another radar control and real time data display node located at WHNT-TV in Huntsville.

3. COORDINATION OF OPERATIONS BETWEEN RESEARCHERS AND BROADCASTERS

Scanning logistics are well coordinated between NSSTC and WHNT-TV through the development of semi-autonomous task schedules. During weather broadcasts, but with no severe weather, the radar operates in back-to-back alternating three-tilt polarimetric rain scans (RAIN1) followed by SUR scans. For periods with no broadcast (the overwhelming majority of the day) and/or weather concerns/interest, the "default" operation mode is currently a cycle of one RAIN1 and one SUR scan every 5 minutes (scan types offset 2.5 minutes). In the event that severe or otherwise significant weather of interest occurs, 2-5 minute polarimetric sector volume scans and/or RHIs are collected by researchers at NSSTC, interleaved with low level SUR scans taken at approximately 5 minute intervals as an update for the WHNT meteorologists. It is important to point out that WHNT-TV meteorologists are breaking away from the familiar TV weather-media paradigm of using continuous low level scans on air, to that of using and broadcasting volumetric data (including RHIs) in their newscasts.

4. SCIENCE

ARMOR and STORMnet instrumentation (Fig. 2) coupled with the oscillating "tropical", and "mid-latitude", climates of the southeastern U.S. greatly facilitate the study of precipitation, cloud and hydrological processes (kinematics, microphysics, electrification, rainfall, runoff etc.) over a wide variety of warm and cold season cloud and precipitation system types. Systems including isolated cumulonimbi, subtropical MCSs, severe tornadic/hail producing convection, broad regions of frontal stratiform rain, and frontal mixed-phase rain/snow boundaries, can all be examined under the broad ARMOR and STORMnet umbrella.

Precipitating systems in each of these “regimes” can be systematically interrogated, displayed and studied by fusing ARMOR polarimetric radar data with data collected by other STORMnet observational platforms (Fig. 5) including: multiple Doppler radars (Hytop NEXRAD radar; Redstone Arsenal S-band Doppler radar); the UAH Mobile Integrated Profiling System (MIPS; 915 MHz profiler, Doppler SODAR, multi-spectral scanning radiometer, laser ceilometer, and surface meteorological instrumentation); NASA Northern Alabama VHF 3-D Lightning Mapping Array (Koshak et al., 2004); and surface mesonet data consisting of automated rain gauge networks(CHARM- Cooperative Huntsville Area Rainfall Measurements; Jedlovec et al., 2002).

To facilitate more complete studies of cloud systems and convective initiation at UAH/NSSTC, and in addition to the HID algorithms, we have recently teamed with colleagues from the Colorado State University CHILL radar to run real time dual-Doppler (ARMOR and Hytop NEXRAD) retrievals at NSSTC. The combined HID and 3-D wind products can then be combined in near real time with LMA total lightning measurements to develop real-time metrics and efficient displays of storm intensity and growth (Fig. 5). Low-level clear-air dual-Doppler scans are further exploited to study boundary layer processes and convective initiation (e.g., Fig. 4)

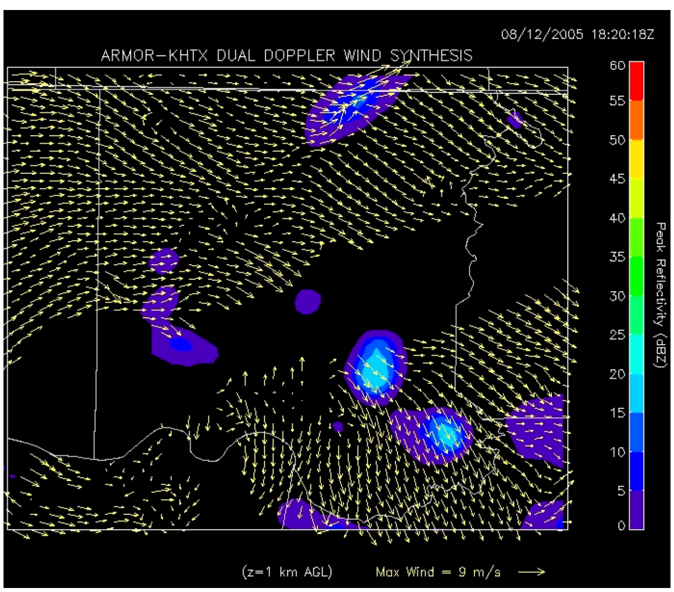

Figure 4. Example of automated ARMOR-KHTX low level (1 km) dual-Doppler wind synthesis output in relatively clear air.

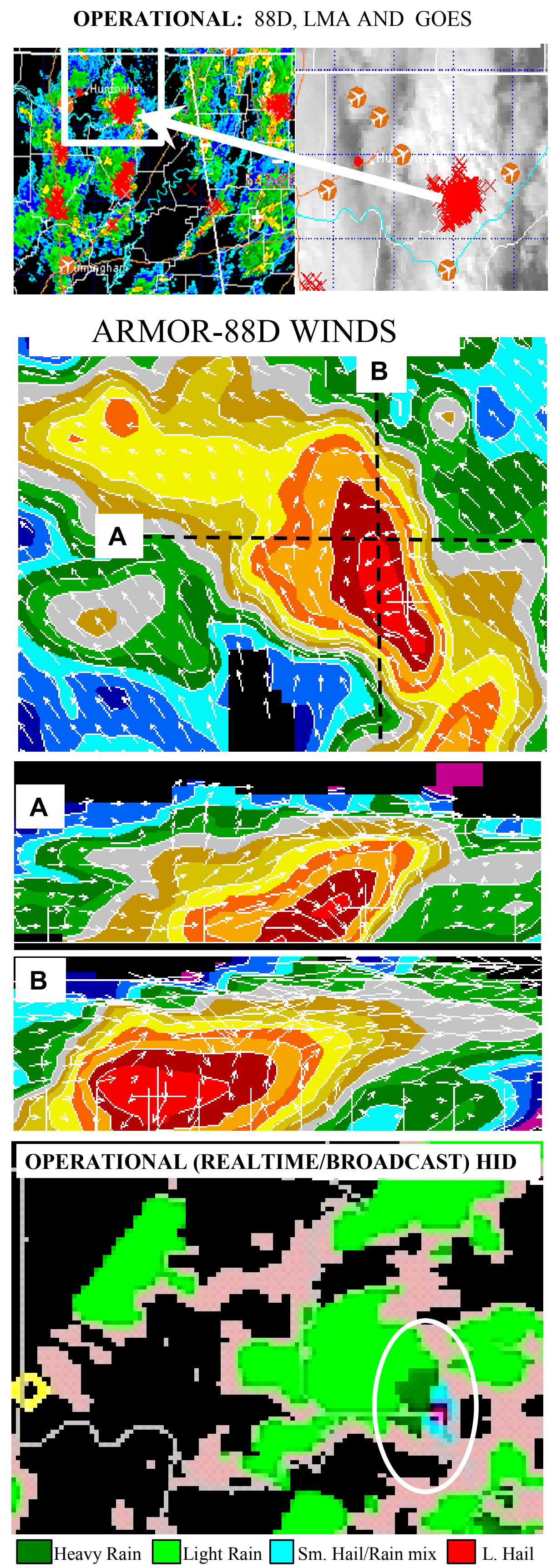

Figure 5. Examples of STORMnet and ARMOR products collected for hail producing convection on 4/7/05. Top: Left, 88D dBZ and NASA LMA total lightning source locations, GOES and LMA for outlined box. Middle, plan and RHI views of storm cross section in outlined box with winds overlaid. Bottom, real-time operational and simplified table-based version (used in WFO and also on air by WHNT) of HID

It is anticipated that the planned continuous daily operation of ARMOR within the STORMnet infrastructure will facilitate end-to-end sampling of precipitation system evolution; from initiation (e.g. boundary identification and wind mapping), to mature precipitation processes- including electrification, to demise. This sampling can further be conducted coincident with overpasses of satellite-based cloud and precipitation remote sensing instrumentation (e.g., platforms such as NASA TRMM, Terra, Aqua, Cloud-Sat, GPM etc.). When integrated with the space-borne observations, analysis of the resulting datasets should prove to be an asset in the quest to improve QPE and radar and satellite remote sensing algorithms of clouds and precipitation.

5. EDUCATION

At NSSTC, real-time display of data is easily facilitated to virtually any UAH Dept. of Atmospheric Science classroom or weather facility (e.g., the WFO). This display ability combined with the ability to remotely control the radar enables combined operational and educational use of the ARMOR by NWS meteorologists, the NASA Short Term Prediction and Research and Transition Center (SPoRT), and UAH graduate students in courses and research focusing on Remote Sensing, Radar Meteorology, and Radar Engineering. Indeed, the Huntsville NWS WFO is one of few offices in the country that has access to real time polarimetric data for support of its warning and decision process.

Finally, it is important to note that the ARMOR radar, as a project, represents a direct mode of technology and research transfer to both the public and private sectors. This transfer is facilitated through interactions between WHNT-TV and the viewing public, and WHNT-TV and NSSTC (e.g., UAH and NASA). Essentially, WHNT-TV's investment in the ARMOR upgrade facilitates new and improved research at NSSTC. In turn, WHNT-TV is able use the advanced technology, products, and training supplied by the project to improve their weather broadcasts and their capacity to keep the viewing public informed. At the same time, the public is made aware of current weather technologies and research in meteorology via the implicit information conduit that WHNT-TV provides to researchers at NSSTC.

6. SUMMARY

The UAH WSR-74C radar (called ARMOR), controlling hardware, and data systems have been upgraded to full dual-polarimetric capabilities in a joint project involving WHNT-TV, UAH, and NASA-MSFC. ARMOR data are used for applied research and education at NSSTC, while WHNT-TV and the NWS also use the data for operational warning and decision making. The use of polarimetric radar data for public safety applications in the real-time operational environment of broadcast meteorology (e.g., WHNT-TV) is unique, and constitutes a new mode of technology transfer from government/academic research activity to the public domain.

Note: Real time ARMOR data can be viewed at: http://www.nsstc.uah.edu/ARMOR

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7. REFERENCES

Bringi, V. N., and C. Chandrasekar, 2001: Polarmetric Doppler Weather Radar. *Cambridge University Press,* 636 pp.

Jedlovec, G. J., P. J. Meyer, and A. R. Guillory, 2002: Inter-comparison of CHARM data and WSR-88D storm-integrated rainfall. *Preprints, 16th Conference on Hydrology*, American Meteorological Society, January 13-18, 2002, Orlando, Florida.

Koshak, W. and coauthors, 2004: North Alabama Lightning Mapping Array (LMA): VHF source retrieval algorithm and error analyses. *J. Atmos. Oceanic Technol*., **21**, 543-558.

Liu, H., and V. Chandrasekar, 2000: Classification of hydrometeors based on polarimetric radar measurements: Development of fuzzy logic and neuro-fuzzy systems, and in situ verification. *J. Atmos. Oceanic Technol.*, **17**, 140-164.

Ryzhkov, A. V., S. Giangrande, and T. Schuur, 2003: *Rainfall measurements with the polarimetric WSR-88D radar*. Report of the National Severe Storms Laboratory, Norman, OK, 73069, 98 pp.

Schuur, T., A. Ryzhkov, and P. Heinselman, 2003: *Observations and classification of echoes with the polarimetric WSR-88D radar*. Report of the National Severe Storms Laboratory, Norman, OK, 73069, 46 pp.

Straka, J. M., D. S. Zrnic, and A. V. Rhyzhkov, 2000: Bulk hydrometeor classification and quantification using polarimetric radar data: Synthesis of relations. *J. Appl. Meteor*., **39**, 1341-1372.

Zrinic, D. S., A. Ryzhkov, J. Straka, Y. Liu, J. Vivekanandan, 2001: Testing a procedure for automatic classification of hydrometeor types. *J. Atmos. Oceanic Tech*., **18**, 892-913