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METEOROLOGICAL OBSERVATIONS AND SYSTEM PERFORMANCE FROM THE NASA D3R'S FIRST 5 YEARS

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Fig. 1. The NASA D3R deployed at Wallops Flight Facility, Wallops Island, VA on March 21, 2014.

The NASA dual-frequency, dual-polarization, Doppler radar (D3R) [1] was conceived and developed to support ground validation (GV) operations of the Global Precipitation Measurement (GPM) mission [2]. The D3R operates in the same frequencies bands, Ku- and Ka-band, as GPM's dual-frequency precipitation radar enabling direct comparisons of microphysical observations of precipitation. The D3R radar is shown in Figure 1. To support the GPM GV mission, D3R substantively participated in four field campaigns in North America with diverse geographic features covering both winter and summer conditions.

The geographic and seasonal variability of observations collected thus far with the D3R enables a unique opportunity for comparing regional and seasonal influences on the microphyical properties of precipitation at Ku- and Ka-bands. To fully utilize the D3R's observations from these diverse deployments, the system's operating conditions and performance are detailed here. To this point, the D3R has archived the in-phase and quadrature data (Level 0) enabling meteorological radar moments to be post-processed, taking advantage of new, advanced signal processing techniques. Approximately 750 TB of uncompressed radar data has been collected and archived.

The GPM GV field campaigns in which the D3R was deployed operationally were the 2012 GPM Cold Season precipitation Experiment (GCPEx) [3], the Iowa Flood Studies (IFloodS) in 2013 [4], the Integrated Precipitation and Hydrology Experiment (IPHEx) in 2014 [5], and most recently the 2015/2016 Olympic Mountains Experiment (OLYMPEx) [6]. In between being deployed for these targeted intensive field campaign operations, the D3R remained actively engaged, conducting both routine surveillance operations and targeted scientific investigations at its various "home sites" including Greeley, CO, Newark, MD, and Wallops Island, VA. The locations that D3R has been deployed and operated are illustrated in Figure 2.

The D3R's primary function has been as an operational research radar enabling both engineering and atmospheric science investigations. As such, the radar has been in various states of continuous enhancement to extend it's capabilities and improve the data quality. Table 1 presents a time line of the locations where the radar was deployed and any relevant engineering advancements that are pertinent to changes in the radar's capabilities.

The radar was designed, assembled, and tested at Colorado State University (CSU). In 2011, the D3R was operated for engineering development purposes. The first operational deployment as a meteorological instrument was for the 2012 GCPEx winter campaign. The specified Ka-band transmitters were still in development and 1 Watt transmitters were used. This demonstrated the radar could operate continually over its lower end of operating temperature regime and proved the radar's systems were robust for sustained operational use. After GCPEx, the radar returned to Greeley, CO to continue with the integration of its full power 40 W Ka-band transmitters.

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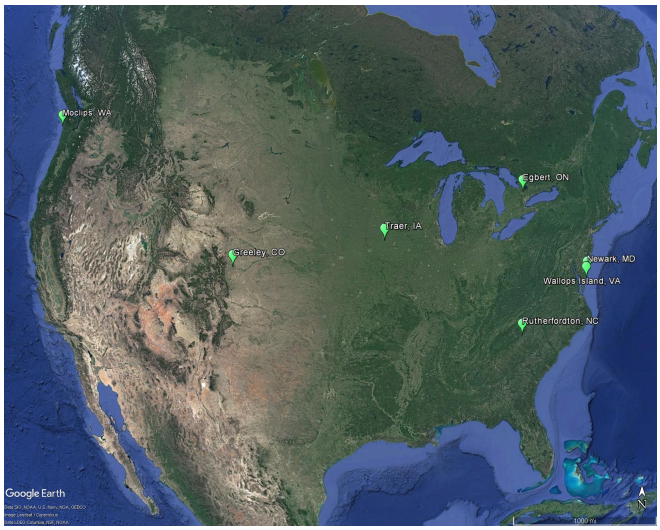

Fig. 2. The locations were the NASA D3R has been deployed and operated.

Table 1. NASA D3R Operation Summary

Dates	Location	Summary
- Dec. 2011	Greeley, CO (CSU)	Three pulses. 1 W Ka TX. No Ka cal-loop.
Jan-Feb 2012	Egbert, Ontario (GCPEx)	
Mar. 2012 - July 2012	Greeley, CO (CSU)	
Aug. 2012 - Dec. 2012	Greeley, CO (CSU)	Offline for Ka transceiver upgrade.
Jan. 2013 - Apr. 2013	Greeley, CO (CSU)	40 W Ka transmitter. Two pulses.
Apr. 2013 - June 2013	Traer, IA (IFloodS)	
Nov. 2013 - Mar. 2014	Wallop Island, VA (WFF)	
Apr. 2014 - June 2014	Rutherfordton, NC (IPHEx)	
July 2014 - Sept. 2014	Newark, MD	
Sept. 2014 - Feb. 11 2015	Newark, MD	Pseudo-random phase code and ALT mode.
Feb. 12 2015 - Oct 2015	Wallop Island, VA (WFF)	New radomes installed.
Nov. 2015 - Jan. 2016	Moclips, WA (OLYMPEx)	
Mar. 2016 - Oct. 2016	WFF	
Nov. 2016 - present	WFF	Ku-band digital receiver upgraded.

During this upgrade the Ka-band transmitter calibration loop was fully integrated and, for both frequencies, a two-pulse design was opted for over the three frequency diverse pulses. This design change allowed for the third frequency sub-band to be used for passive observations. Among other things, this enables robust radial noise power estimation.

The 2013 IFloodS field campaign was the first intensive operation of the D3R with Ka-band's high power transmitters providing 16 dB of additional sensitivity for Ka-band observations over the 1 Watt version. The successful operations marked a milestone for D3R, completing the demonstration of continuously operations in winter (GCPEx) and summer (IFloodS) environments. With the conclusion of IFloodS, D3R transitioned away from engineering centric use and began to focus on investigation into atmospheric processes. As part of the transition, the radar was deployed at Wallops Flight Facility (WFF), Wallops Island, VA.

In 2014, D3R was sent to Rutherfordton, NC as part of the IPHEx field experiment where it again performed in a hot environment observing convective initiation and orographic effects on precipitation. After completion of the experiment, D3R was deployed to a site in Newark, MD to be collocated with the S-band NASA polorimetric radar (NPOL). In September/October 2014, the waveform generator and digital reciever were modified to implement pseudorandom phasecoding as well as alternate transmit, simultaneous receive (ALT) mode. The phase coding enabled development of detection and suppression of second trip echoes. The ALT mode functionality enables deeper microphyiscal investigations through the addition of linear depolarization ratio as an observable. In Early 2015, the radar was moved back to WFF where it was in closer proximity to other precipitation observing ground instruments. The D3R was deployed to WA for two and a half months at the end of 2015 through early 2016 for OLYMPEx. After the campaign's conclusion, the D3R returned the WFF where it is currently undergoing an upgrade of its digital receiver system to further enhance functionality and ultimately, improve sensitivity through advanced signal processing techniques.

During the D3R's development and operations, it was deployed with multiple other instruments within it's observational domain. These instruments include other ground-based, dual-polarization weather radar systems, multi-frequency radiometer systems, lidar, ceilometers, w-band radars, rain gauges, distrometers, and on occasion, airborne instruments. In this work, the D3R's observations will be compared to a subset of the available instruments which includes the NASA NPOL S-band radar, Autonomous Parsivel Unit (APU) disdrometers and two-dimensional video disdrometers (2DVD), and rain gauges.

The D3R's operational history will be presented and quantitatively evaluated considering observations from more than 5 years since its inception. The system and signal processing research, making the D3R a state of the art research weather

radar, will be detailed. As part of quantitatively evaluating radar observations at attenuating frequencies (such as D3R's Ku and Ka bands), accurate estimation and correction of attenuation is critical. The attenuation relations from the D3R's deployments will be compared and the microphysical significance of these relationships will be discussed.

Geographic and seasonal variation strongly influences the characteristics of precipitation. Using observations over D3R's rich observational history, a quantitative evaluation of the spatial and temporal variability of the precipitation will be considered and discussed. The results will be compared as they relate to both seasonal and geographic effects on precipitation microphysics.

1. REFERENCES

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