1P.8 THE APPLICATIONS OF NASA'S POLARIMETRIC RADAR IN MID-LATITUDE COASTAL VALIDATION SITE

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1. INTRODUCTION

Wallops Island, Virginia (37.855˚ N, 75.513˚ W) is located along the mid-Atlantic coastal region of the Unites States, and has been considered as a candidate for a mid-latitude coastal site for the NASA's Precipitation programs. Wallops Island receives 980 mm of precipitation on annual average with only 28 mm difference between the months that receive maximum and minimum precipitation. The precipitation is driven by mid-latitude frontal systems in winter and convective showers in summers. Wallops Island also occasionally receives remnants of tropical storms during the Atlantic hurricane season.

As part of the NASA TRMM ground validation program, a comprehensive ground-based observational network including rain gauges and distrometers has been installed on the Wallops Island and its surrounding areas (Fig. 1). In this ground validation site, a key element will be the recently developed NASA's polarimetric radar (NPOL), which is anticipated to be used to improve the precipitation estimation. The NPOL radar has a unique flat panel antenna that is hexagonal in shape and 5.5 m across. Compared to the traditional parabolic antenna, the flat antenna is easily transportable and less susceptible to high winds. This linearly polarized (H and V) radar provides polarimetric products including reflectivity (Zh), radial velocity (Vr), differential reflectivity (Zdr), and differential propagation phase (□ dp). Presently, the NPOL radar was operated at Oyster, Virginia (37.383˚ N, 75.983˚ W). The primary objectives of our study are: 1) to develop a standard procedure to quality control and process the large volumes of polarimetric radar data, and 2) to evaluate the performance of the NPOL radar through a case study.

2. CASE OVERVIEW AND DATA EVALUATION

On 25 June 2004, under the influence of a cold front passage, a set of convective rainband passed the mid-Atlantic coast and caused widespread rainfall in the region. The operation of the NPOL radar was from 1600 to 2330 UTC with continuous 6-min 360° surveillance scans at 10 elevations from 0.5° to 20°.

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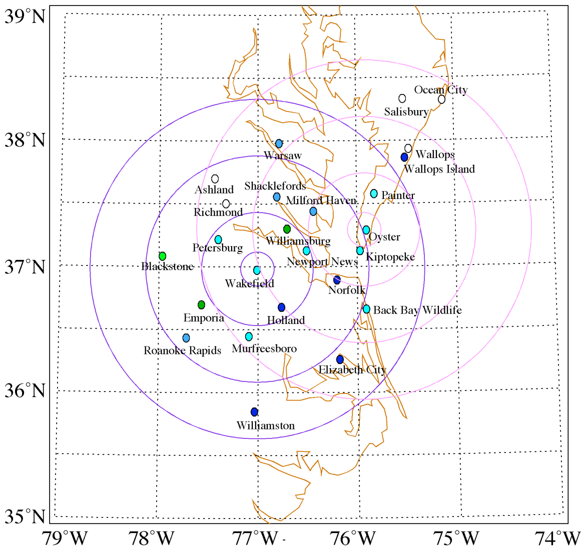

Fig. 1 Greater Wallops radar rain-gauge network.

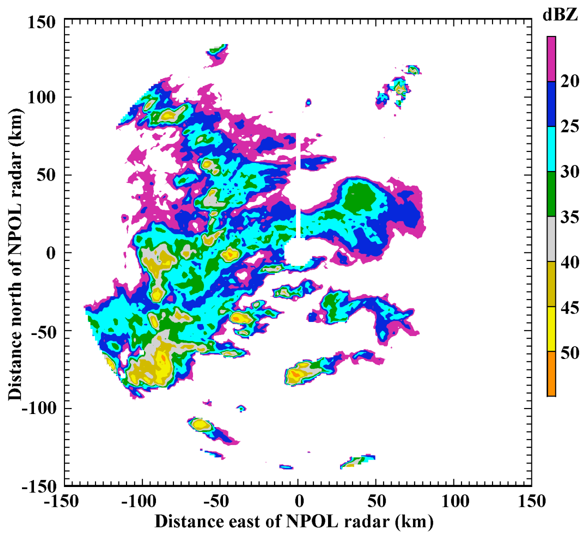

Fig. 2 NPOL radar reflectivity (dBZ) at 3 km MSL valid at 1843 UTC, 25 June 2004.

The rainband moved into the NPOL observational domain at 1615 UTC. The eastward propagating rainband enhanced in both size and intensity during the next 2.5 hour. At 1843 UTC, the main feature in the domain was the north-south-oriented frontal rainband with a width of 70-100 km (Fig. 2). This rainband has a maximum reflectivity of 58 dBZ recorded at 2125 UTC to the south of NPOL (not shown). The whole system weakened and moved out of the radar domain around 2330 UTC.

The original NPOL data was quality controlled by using the empirical method described by Carey et al. (2000). Light thresholding of range gate data of $\rho_{HV} \geq$ 0.6 and $\sigma(\Phi_{dp}) \leq$ 18° was used to remove clear air, clutter and other non-precipitation echo. The quality controlled radar data were then interpolated to a Cartesian grid using the National Center for Atmospheric Research (NCAR) SPRINT software (Mohr et al. 1986) for further analysis.

To evaluate the performance of NPOL radar, we first compared the reflectivity data with Wakefield NEXRAD radar and Wallop S-band SPANDAR radar, which are 102 km southwest and 82 km northeast to the NPOL, respectively. With different radar characteristics, start and end time of the volumes from each radar, we should not expect "point-to-point" match of the data. As shown in Fig. 3, the slope of the linear interpolation for two S-band radars, NPOL and SPANDAR, in general was close to the perfect correlation (1:1) line. The NPOL reflectivity data are slightly, about 0.7 dBZ, higher than the SPANDAR reflectivity data. The correlation between NPOL and NEXRAD was about equally good (not shown). However, the NPOL had reflectivities about 1.7 dBZ higher than NEXRAD.

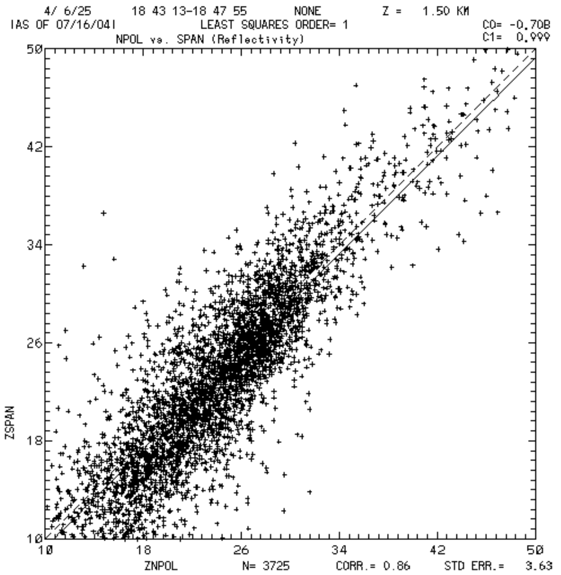

Fig. 3 Radar reflectivity comparison between NPOL and Wakefield NEXRAD at 1843 UTC, 25 June 2004.

Next, we estimated any possible Zdr bias by examining the histogram of Zdr in anvil echo. Using raw UF data, we isolated range gates characterized by low-to-moderate reflectivity (15-25 dBZ) at high elevation angle (≥15 deg) well above the bright band (> 6.0 km) at moderate ranges (10≤Range≤60 km). The goal is to isolate dry, low density aggregates which should have near zero Zdr. We found that Zdr had a positive bias of +0.46 dB. Strangely, there was a periodic behavior in the frequency histogram. After every two high frequency samples, there was a low frequency sample about half of the value from the trend of the previous two points. This may suggest a data digitization problem. Zdr should be accurate to 0.1 dB for quantitative use. Given this odd frequency histogram, we would suggest that NPOL has a potential problem, possibly with the way the data were recorded.

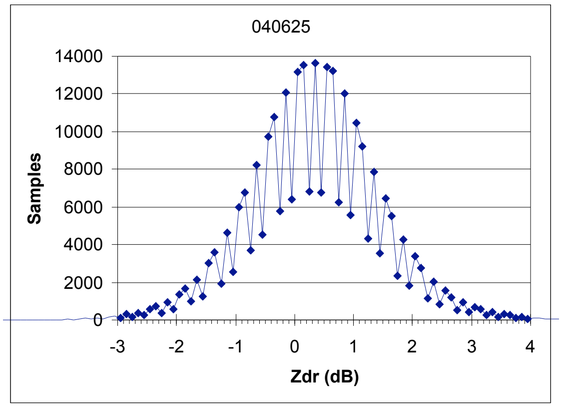

Fig. 4 Z_{DR} histograms from NPOL at 1843 UTC, 25 June 2004. Bin size is 0.1 dB.

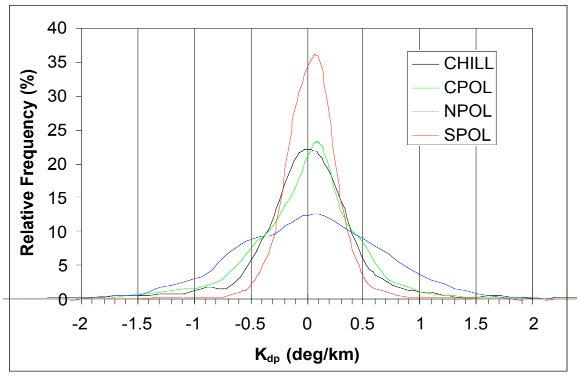

Fig. 5 Relative frequency histogram of Kdp in "drizzle."

When visually examining the specific differential phase (Kdp) from NPOL (not shown), our impression was that the data were reasonable, but very noisy. This was confirmed from the relative frequency histogram of Kdp in Fig. 5. The histogram was made from the data collected in the light rain region when Kdp should be zero. Any deviation from zero is associated with measurement error. The NPOL K_{dp} distribution in drizzle is relatively flat with a significant fraction of |Kdp| (~5%) even beyond 1 ° km^{-1}. For the comparison purpose, we also plotted relative frequency histogram of Kdp from a case observed by other established research polarimetric radars, i. e., CSU-CHILL (16 July 2004), NCAR SPOL (26 January 1999 from TRMM-LBA, Cifelli et al. 2002), and BMRC CPOL (24 May 1998 from SCSMEX, Wang 2004; Wang and Carey 2004), also in a widespread rain event. All plots were for the carefully selected light rain area. Apparently, the distributions of K_{dp} for the other radars are much more peaked around zero.

After determining the bias of Zdr, we were able to calculate Kdp from Z and Zdr as suggested by Vivekanandan et al. (2003):

$$Kdp = 3.32 \times 10^{-5}\, Z\, Zdr^{-2.05}.$$

A comparison between the calculated Kdp and the observed Kdp may also provide us some idea if there are any significant biases in Zh. Our results gave an estimation of positive Zh bias of +0.8 dBZ. This had a good agreement with the comparison with the SPANDAR and NEXRAD radar mentioned above.

3. "WET ANTENNA" PROBLEM

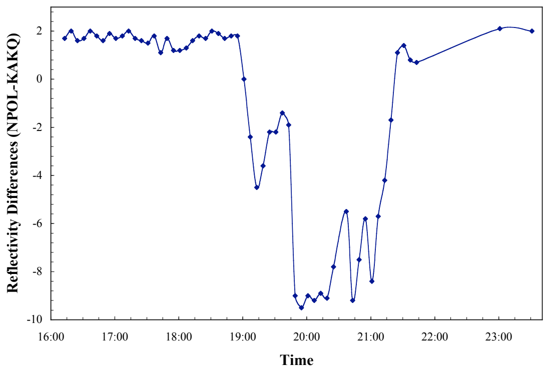

Fig. 6 Times series of reflectivity comparison between NPOL and NEXRAD. NEDRAD data was not available between 2143 and 2301 UTC.

From previous field experiment, e.g., the Cirrus Regional Study of Tropical Anvils and Cirrus Layers – Florida Area Cumulus Experiment (CRYSTAL-FACE), we knew that the NPOL radar suffered a serious reflectivity attenuation problem when the antenna was wet. It is our interest to use the present case study to quantify the influence of wet antenna. The rain gauge data collected from Oyster, VA showed that, at the radar site, the rain started at about 1845 UTC and ended at about 2050 UTC with a total of 8 mm rain recorded. The time series of reflectivity differences between NPOL and NEXRAD radars (Fig. 6) showed that the NPOL was generally 1.5-2 dBZ higher than NEXRAD till 1855 UTC. After the rain started, the NPOL reflectivities began to drop. A drop of 6-6.5 dBZ appeared during 1855 to 1913 UTC. There was a recovery of about 3 dBZ during the next 24 min. The most dramatic change of NPOL data occurred between 1943 and 1949 UTC. There was a sudden reflectivity drop of 7-8 dBZ (Fig. 6). The NPOL reflectivities were about 9 dBZ lower than NEXRAD reflectivities throughout the heavy rain period. After the rain ended, it took about 40-50 min for the antenna to back to its normal status.

4. OPTIMAL RAINRALL ESTIMATION

Table 1. NPOL Rain Rate Estimation

Conditions: a. $Zdr \geq 0.5$ dB b. $Zh \geq 35$ dB and $Kdp \geq 0.5°\ km^{-1}$
Equations: 1. Both conditions a. and b. are satisfied: $R(Kdp,Zdr) = 65.24 \cdot 10^{-0.060Zdr}(Kdp)^{0.995}$ 2. Only condition a. is satisfied: $R(Zh,Zdr) = 0.0015 \cdot 10^{-0.095Zdr}(Zh)^{0.97}$ 3. Only condition b. is satisfied: $R(Kdp) = 40.51 \cdot (Kdp)^{0.759}$ 4. None of condition a. or b. is satisfied: $R(Zh) = 0.029 \cdot (Zh)^{0.636}$

The main objective of this project is to use the polarimetric radar measurements to improve the radar rainfall estimation. The ultimate goal is to use the improved ground-based radar rainfall estimation to valid the rainfall estimation by satellite, e.g. TRMM and GPM. Presently, the rain rates for each radar volume were calculated using an optimization technique with the parameters Zh, Zdr, Kdp (Carey and Rutledge 2000). With this method, the measurement capability of each polarimetric variable is maximized. Combinations of those variables in rain rate equations (Bringi and Chandrasekar 2001) are described in Table 1. The parameters in the equations were determined based on Wallops distrometer data analysis.

Considering that the NPOL data was contaminated by the "wet antenna" after 1850 UTC, we constructed rain map of the NPOL observational domain for the periods of 1613-1849 UTC, 25 June 2004 (Fig. 7). Compared to the traditional Z-R relationship, the optimal polarimetric method provided significantly higher rainfall amount in the heavy rain areas, especially in the strong convective region. This method was believed to give rainfall estimation close to the reality. We also calculated the frequency of each method listed in Table 1 used. The most frequently used method was R(Zh, Zdr), accounted for 54%. The simple Z-R relationship was used in 45% of the data. Even for such a strong convective case, the usage of Kdp was very rare. R(Kdp,Zdr) and R(Kdp) were used 1% and 0.1%, respectively, throughout the periods.

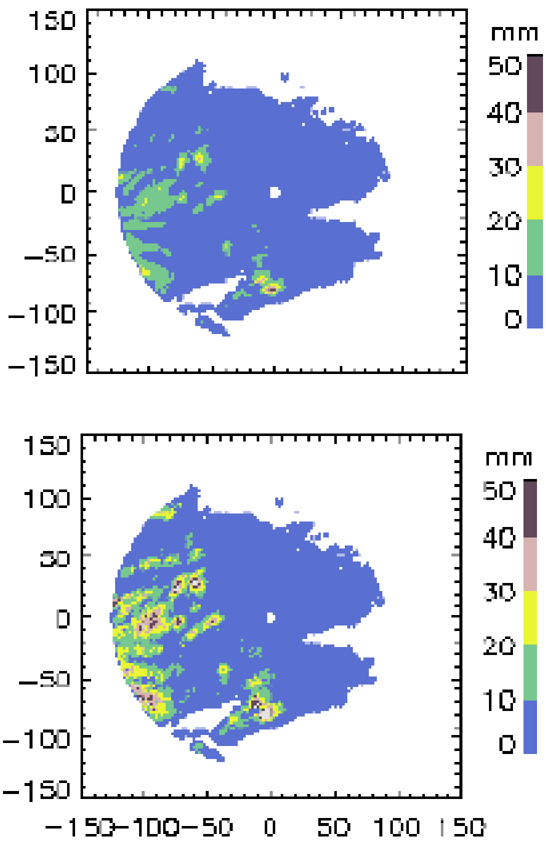

Fig.7 Total rainfall estimated from the Z-R relationship (top) and optimal polarimetric method (bottom) for 1613-1849 UTC, 25 June 2004.

5. FUTURE WORK

The process of data from 20 rain gauges within 150 km range from NPOL radar is in progress. The comparison between the NPOL estimated rainfall and measured rainfall will be presented at the conference. More distrometer data for different types of precipitation cases at greater Wallop region will be analyzed to fine tune the parameters used in Table 1. As to the NPOL radar, more engineering work to fix the hardware defects, such as “wet antenna” issue, is a must. More cases will be collected and studied with the similar approach to the case presented here. The large number of samples will give us more confidence about the work we have done. Once a reliable rainfall estimation from NPOL radar is established, it will be used to valid satellite (SSM/I, TMI, AMSU) rainfall products.

Acknowledgements

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