THE FRONT RANGE PILOT PROJECT FOR GPM

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1. INTRODUCTION

In the summer of 2004, demonstration of the supersite ground validation (GV) concept for the Global Precipitation Measurement (GPM) mission was carried out in the form of a Front Range Pilot project (FRP), involving scientists from CSU and NOAA's Environmental Technology Laboratory and Aeronomy Laboratory. The project's specific aims included evaluation of dual-wavelength polarimetric radar observations for estimating rainfall rates in moderate to heavy rainfall, as well as developing errors associated with these techniques by comparison to ground-based measurements from gauges and disdrometers. To accomplish this component, the project used the S-Band CSU-CHILL radar at Greeley, CO and NOAA-ETL's X-Band radar at Erie, CO. The X-Band radar's improved phase sensitivity in light rain was also used to explore how polarimetric based techniques could be extended to light rainfall regimes. The pilot project also focused on selection of UHF profiler frequencies that would best complement S-Band profiler measurements to allow for the most accurate retrieval of drop size distribution characteristics. A further goal of the pilot project was to perform quantitative comparisons of drop size distribution (DSD) characteristics between the profilers and scanning radars in order to evaluate assumptions in the scanning radar retrieval technique (e.g., equilibrium drop shape relationship) as well as spatial variability of the DSD. We also looked to demonstrate the complimentary role played by rain gauges and surface disdrometers (both 2-D video and J-W types) in determining the error characteristics of multi-frequency profiler DSD estimates and dual-frequency radar DSD and rain estimates.

2. EXPERIMENTAL DESIGN

A diverse set of instrumentation was available for the pilot project, as illustrated in Fig. 1. The CSU-CHILL National Radar Facility was operated at its home base in Greeley, CO (www.chill.colostate.edu). Both the BAO and Platteville sites used profilers operating at 3 frequencies: one at S-Band to measure precipitation velocity spectra (and estimate DSD), and two in the UHF band: 915 and and 449 MHz. The UHF profilers are being evaluated to determine their ability: 1) to resolve both the clear air and precipitation components of the radial velocity spectra in different precipitation environments (e.g., light vs. heavy rain); and 2) in concert with the S-Band profiler data, provide dual-wavelength DSD parameter retrievals with the smallest errors. Each site was instrumented with at least one J-W impact-type disdrometer, tipping-bucket rain gauge, and surface meteorological station. The BAO site also included CSU's 2-D video disdrometer (after June 1).

2.1 Radar scanning

The NOAA X-Band radar scanning sequence included 2 low-level PPIs and 2 RHIs covering the Platteville and BAO sites. Gate to gate resolution was set to either 150 m or 112.5 meters, giving a maximum range of 38.8 or 28.8 km, respectively. The CSU-CHILL scan sequence included a sector of approximately 40 degrees azimuth over the entire X-Band scan sector (and the instrumented sites), and specific RHIs over the BAO and Platteville instrumented sites. CHILL used two scanning modes depending on the rainfall regime: (1) a high-resolution 75 m range resolution low level scan mode matching with a 2-3 minute scan repeat cycle (allowing high-resolution quick scanning of surface rainfall), and (2) a standard resolution 150 m range resolution volume scan mode with a 6-8 minute scan repeat cycle (allowing storms' vertical reflectivity and microphysical structure to be scanned by CHILL). Research is presently underway to determine the best filtering parameters for converting differential phase to specific differential phase at the reduced gate resolution of 75 meters (since most work to date in this area has focused on the more traditional 150 m gate spacing).

Combining the S- and X-Band radar polarimetric measurements will allow comparison of measurements of rain rate and DSD characteristics, and evaluation of errors in those fields from both instruments. By using CHILL's unattenuated reflectivity field, it will be possible to evaluate the X-Band's self-correcting specific differential phase method of accounting for attenuation. In addition, the X-Band system's higher differential phase sensitivity in light rain will allow the quantification of errors in rain estimates in light rain from the less phase-sensitive S-Band CHILL radar. In addition, the measurements from the scanning radars will be compared

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with the estimates of rain rate and DSD characteristics from the surface disdrometers, profilers, and rain gauges to determine error characteristics.

2.2 Project timeline

The formal period of data collection period for the Front Range Pilot Project was 15 May, 2004 through June 21, 2004. Table 1 shows a list of cases collected during the pilot. Weather conditions were relatively dry during the first half of the project. The second half of the project brought more favorable conditions with a number of continuous light and heavy rain events (and at least one significant hailstorm) being observed. The heavy rain events are useful for comparing the S-band unattenuated rain estimates against the X-band attenuation corrected rain estimates. The X-band reflectivity and differential reflectivity fields are corrected for attenuation using the differential phase (phi dp) field. In addition to the cases collected during the formal data collection period, target of opportunity cases were collected after 21 June. These cases (not shown in Table 1) included scattered light rain showers on 30 June, showers along with a bright band event on 15-16 July, widespread rain with embedded cells and occasional heavy rain on 22-23 July, and widespread rain with strong embedded convection on 23-24 July 2004. All in all favorable weather conditions occurred in the pilot, even though Colorado is still in a period of drought.

Table 1. List of cases collected during the GPM Pilot Project from 15 May 2004 through 21 June 2004.

GPM-FRPP Case Summary - 2004

Possible Usefulness of Collected Data:

A= Polarimetric radar estimates of rainfall rates and drop sizes compared with profilers, disdrometers, or rain gauges
B = Testing X-band attenuation corrections using CHILL as un-attenuated reference
C = Basic studies of severe storm structure, kinematics, etc.

Case	Description	A	B	C	Problems
15MAY	weak convective clouds with sprinkles		x		
17MAY	conv. sprinkles				
20-21MAY	supercell thunderstorm with hail and tornadoes	x (PLT)	x	x	
22-23MAY	rainbands, one became MCS with hail	x (PLT, BAO)	x	x	
24-25MAY *	numerous thunderstorm cells	x (PLT, BAO)	x		BAO disdrom down, CHILL scanning stopped
29MAY *	convective cells, stratiform BB rain	x (PLT)	x		
4JUNE	conv. cell near Broomfield and farther south	x (BRF gauge?, urban flood gauge network?)			
9JUNE	nocturnal thunderstorms, mostly along foothills	x (BAO)			CHILL not on late
9-10JUNE *	numerous showers	x (PLT,BRF)	x		X-band not on early
12JUNE	brief showers	x (BAO)	x		
14-15JUNE	small convective showers in sector	x (TCA gauge?)	x		BAO disdrom down late
16-17JUNE *	light rain, then stronger cells, good rain accumulations	x (BAO, PLT)	x		
17-18JUNE *	widespread rain, good rain accumulations	x (BAO.PLT)	x		CHILL down late
18-19JUNE *	stratiform rain, good rain accumulations	x (BAO, PLT)	x		CHILL not on early
19-20JUNE *	showers in sector, some time series	x (BAO, PLT)	x		short outages at x-band
21JUNE *	line of moderate rain followed by light widespread rain	x (BAO, PLT, BRF)	x		X-band not on early

* = higher priority cases for analysis

Additional post-project data were collected independently by both CHILL and X-band for storms occurring on:
30JUN04-01JUL04
15JUL04-16JUL04

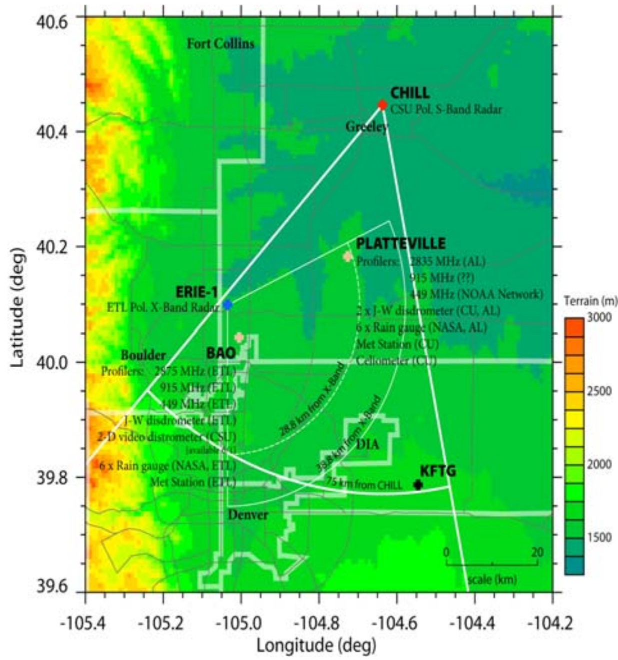


Fig. 1. Arrangement of observational platforms along the Front Range of Colorado used in the GPM Pilot Project.

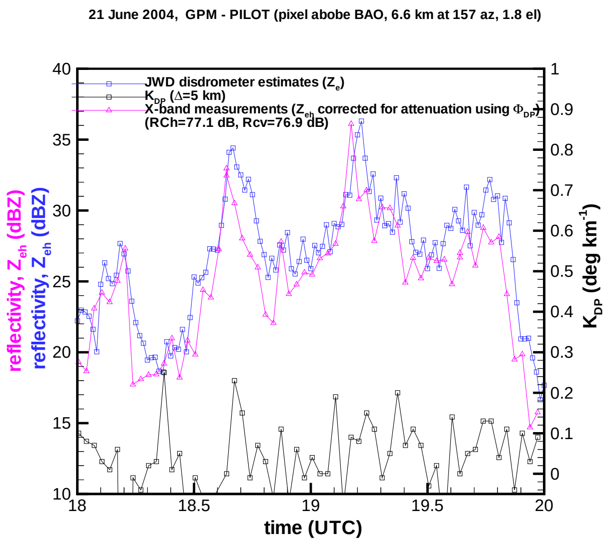
3. PRELIMINARY RESULTS

In this section we concentrate on showing examples of data collected by the various platforms. Since the project ended just a few weeks ago, there has been no time for comprehensive analyses. More detailed results will be presented at the conference.

One focus of the pilot project was to evaluate the use of X-band polarimetric data to map rainfall at lighter rain rates (lower reflectivities) compared to what is possible at S-band.

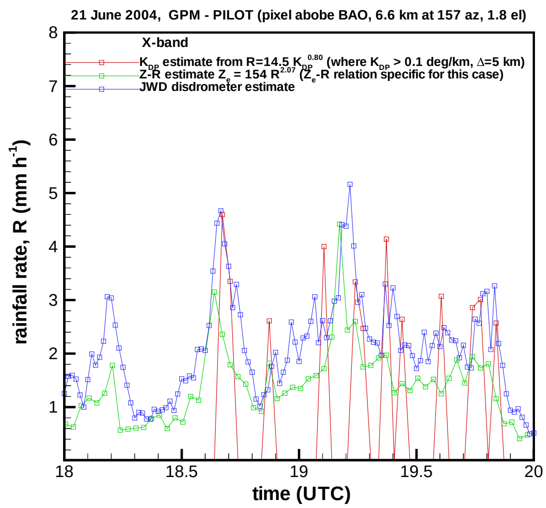
For a given rain medium, the X-band differential phase is roughly a factor of three larger than that at S-band. Provided this lower differential phase (and the derived specific differential phase field) is above the noise threshold of the radar, a R-K_{dp} rain estimate is possible. Past studies indicate that X-band specific differential phase is reliable at reflectivites > 28 dBZ, compared to S-band minimum reflectivity of 36 dBZ. Thus one would expect that the X-band system, when coupled with S-band, would allow for a large portion of the rain rate spectrum to be measurable with polarimetric techniques. In particular, the X-band measurements should work well in even stratiform precipitation. In addition to rain mapping, other variables associated with the DSD can be determined, through power law relationships with polarimetric variables, such as the mass-weighted mean diameter D_m ($D_m = aZ_{dr}^{b}$). An example of such was obtained on 21 June.

Fig. 2. Plot of time series data for 21 June. Blue line is reflectivity estimated from the Joss Waldvogel disdrometer operating at the BAO site. Reflectivity measured by the NOAA X-band radar (cyan line). Kdp, specific differential phase esti mated by the X-band radar (black line).



This time series shows excellent agreement between the reflectivity determined from the disdrometer and the observed reflectivity. Values of specific differential phase above 0.1 deg/km are considered reliable to provide a rainfall estimate based on the R-K_{dp} estimator. Rain rate estimated from the K_{dp} field is shown in Fig. 3. Excellent agreement is found

Fig. 3. Rain rate estimated from K_{dp} ($R = 14.4K_{dp}^{0.86}$), measured by the JW disdrometer and estimated from an –R-Z formula.

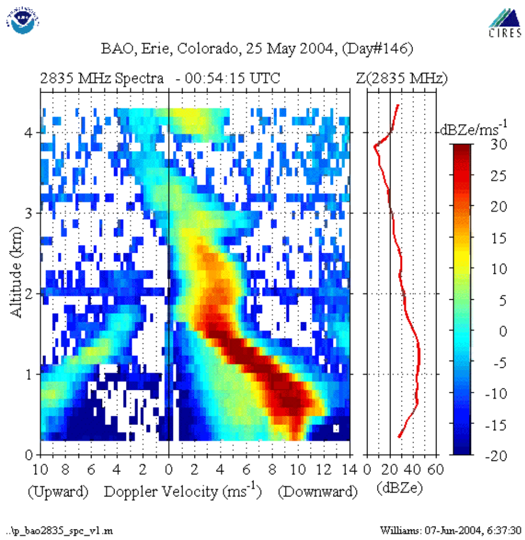


with the JW disdrometer-derived rain rate, for K_{dp} values above the system noise level of 0.1 deg/km. It is important to note that this agreement is found for this low rain rate event, with rain rates between 1-5 mm/h, corresponding to reflectivities between 20-35 dBZ. Estimates of rain rates of these values by the polarimetric method is not possible at S-band as the associated K_{dp} at S-band would be within the system noise limit This case serves to illustrate the ability of X-band polarimetric radar to extend rain mapping to lower reflectivities. Work is also underway to compare the polarimetric-based X-band rain estimates in lighter rainfall regimes to those at S-band using Z-R estimators.

NOAA Aeronomy Lab and Environmental Technology Lab profilers were also deployed at the BAO and PLT sites, consisting of 449 MHz, 915 MHz and S-band profilers at each location. The pilot project wished to focus on retrieval of DSD parameters and microphysical processes from the profilers, and to evaluate their utility in providing information on the vertical structure of precipitation in concert with the polarimetric-based rain rates. An example of the S-band profiler's ability to provide information on the vertical structure of precipitation is shown in Fig. 4.

Fig. 4. S-band profiler data from the BAO site on 25 May 2004 associated with the passage of a convective cell. The

shaded plot indicates the power spectrum of Doppler velocities.



Multiple spectra associated with rain, and small hail (from left to right, downward velocities) are evident and demonstrate the detail in vertical structure that can be revealed from the S-band profiler. The upward velocities on the left side of the figure are caused by a Doppler processing artifact. Work is presently underway to derive the vertical structure of the DSD from the available profilers. Information on the vertical structure of the DSD is an important parameter in validating the GPM-based satellite retrievals. Thus profilers are expected to play an important role at the GPM supersites.

4. CONCLUSIONS

The GPM pilot project assembled a unique set of observational platforms to study precipitation vertical structure and diagnose precipitation rates. Light to heavy rain events were observed, including a few hailstorms. One such heavy precipitation case is shown in Fig. 5.

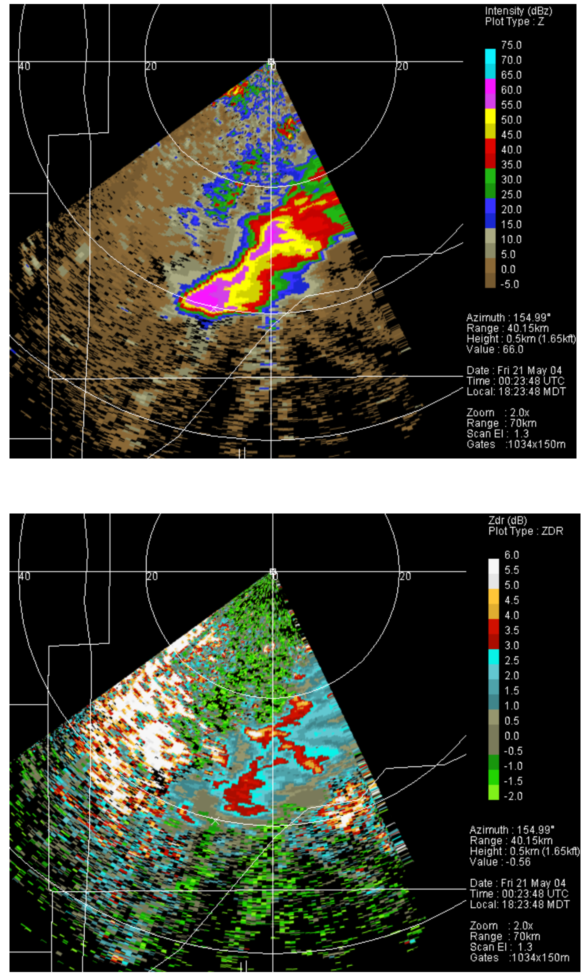


Fig. 5. a) Reflectivity from the CHILL radar on 21 May 2004. b) Differential reflectivity. A classical hail signal is evident near 200 degrees/40 km where reflectivities exceed 60 dBZ and Z_{dr} is zero.

This case is expected to provide an excellent case to evaluate the utility of the X-band in mapping large rain rates (50-100 mm/h in this case). X-band data at higher rain rates are subject to both specific and differential attenuation. Attenuation correction is done using differential phase data. The CHILL S-band data are essentially free of attenuation in heavy rain. Studies are underway to evaluate the X-band reflectivity and differential reflectivity fields after correcting for attenuation to the same fields at S-band. In this manner the capabilities of X-band to map heavy rainfall can be properly assessed. Polarimetric-based X-band rain mapping was demonstrated at relatively light rain rates, below those that can be measured with S-band polarimetric measurements.

The pilot project evaluated instrumentation envisioned to be deployed at the GPM supersites. Only after more detailed inspections of the data can specific recommendations be made.

5. ACKNOWLEDGEMENTS

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