CHILL RADAR NEWS

January 2004 | Twelfth Edition

Overview *(by Prof. Steven A. Rutledge, Scientific Director)*

Aerial view of the CSU-CHILL Radar Facility site. Picture taken by Tom Warner, pilot of the South Dakota School of Mines & Technology T-28 research aircraft.

The CHILL radar arrived at Colorado State University in June of 1990 from the Illinois State Water Survey. At that time, it was designated as the CSU-CHILL National Radar Facility and has since been operated by CSU as an NSF national facility. Over the course of the last 13 years, the facility has undergone a substantial facelift. The first major improvement to the radar came in the form of a new, high performance antenna in the 1993-94 timeframe. This antenna offered considerable improvement over the old antenna, with reduced sidelobes and greatly improved cross-polarization performance. In the 94-95 period, we acquired a new user van that now serves as a comfortable and roomy operations center. Also, in this same time period, the CHILL was transformed into a dual-transmitter, dual-receiver configuration, eliminating the need for the ferrite polarization switch. NOAA/NSSL provided a surplus FPS-18 transmitter for this upgrade. With the switch eliminated, we could now achieve the full dynamic range of L_{dr} measurements offered by the new antenna (approximately –34 db), improved sensitivity and more reliable measurements of Z_{dr}. The dual-transmitter configuration could be operated in a simultaneous mode, or traditional staggered (H,V,H,V….) mode. Measurements of the full covariance matrix were then possible. In 1999 we transitioned to the Lassen DRX signal processor and digital (dual) receiver system. Throughout this period, we developed and installed multiple, real-time calibration systems to constantly monitor the full data stream. Courtesy of the Illinois State Water Survey, we received the HOT radar in 1997, and by summer 1998, had it fully operational 48 km north of CHILL. On the very first day of operation of HOT (now known as the PAWNEE radar), we captured a marvelous dual-Doppler, polarimetric dataset on a supercell! We maintain the CHILL/PAWNEE systems as the only S-band dual-Doppler research network in the U.S.

Our immediate future upgrades are two-fold. First, under the leadership of Prof. V. N. Bringi (CHILL Co-PI), CSU was recently awarded a Major Research Instrumentation grant from the NSF to purchase a new antenna. This antenna is presently being developed by VertexRSI and is scheduled for delivery in spring 2005. This new antenna is an offset Gregorian antenna, and will be the first of this type to be mated with a high power, S-band weather radar. The new antenna will provide markedly reduced sidelobes compared to the current antenna (8 db reduction, two-way) and improved cross-polarization performance. I like to think of the new antenna as providing much sharper views of storms (especially strong storms with sharp gradients) comparable to what corrective lenses do for one's vision. The second major improvement is focused on shifting the dual-transmitters, receivers and signal processors to the "old" CP-2 transmitter trailer. This trailer is better for transporting the radar system compared to the current trailer, and will also allow the hardware to be operated in a cleaner, air-conditioned environment. This new trailer is expected to be fully configured by spring 2005.

A major contribution of the facility has been the development of the V-(Virtual) CHILL software package led by Prof. V. Chandrasekar (CHILL Co-PI) and D. Brunkow (CHILL Chief Engineer). V-CHILL allows remote users, in particular, any classroom that has Internet connectivity, to fully access CHILL data in real-time, and to control the scanning of the antenna. V-CHILL also features an audio/video conferencing capability, allowing lectures to be delivered from CHILL and questions fielded from the remote classroom. V-CHILL has been a huge success, and is used today by many universities on a regular basis. At present we are developing a JAVA version of V-CHILL to provide even easier access to CHILL via the Internet.

The CSU-CHILL radar facility has supported a significant number of projects since arriving at CSU. In terms of formal, NSF-approved projects, CHILL has sup-

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Overview *(continued)*

ported 25 such projects, beginning with WISP (Winter Icing and Storms Project) in 1991. With the exception of STEPS in summer 2000, all of these projects have been carried out at CHILL's home base in Greeley, CO. STEPS was a very successful remote deployment for CHILL. We plan to increase our support of remote deployments. In addition to these formal NSF projects, CHILL has supported nearly 60 "20-hour" projects. In these projects, investigators are provided approximately 20 hours of radar time to study specific weather phenomenon at CHILL's home base. These projects have spanned a huge range of scientific interests and have served the university, federal lab, and operational communities (e.g., the National Weather Service). We also routinely operate CHILL whenever interesting weather is expected. Certainly our unique dataset on the 1997 Ft. Collins flood was obtained in this manner, as were data on the spring 2003 northeast Colorado blizzard. These case studies are maintained via an on-line archive for community access.

As you can readily sense, the CHILL has undergone major changes in its time at CSU, and has played a key role in the science of radar meteorology. We look to do more of the same in the future.

2003 Operations Summary *(by Pat Kennedy, Facility Manager)*

The CSU-CHILL Facility supported two NSF-funded projects and four smaller 20 hour projects during 2003. Additional "target of opportunity" data were also collected during a major snowstorm that struck the area in March.

The radar facility supported an NSF-sponsored Research Experiences for Undergraduates (REU) project during the summer months. The 2003 project involved a group of six students, five of whom were from out-of- state institutions. At the CSU-CHILL site, the students were given introductory lectures on the principles of radar engineering and on applications of meteorological radar data. Over the course of the summer the class also received additional tours and presentations at atmospheric research facilities operated by NCAR and NOAA in the Colorado Front Range area. The students each made final project presentations based on their research activities over the course of the summer. Additional details are available at:

http://www.engr.colostate.edu/ece/pages/reu_main/2003_studentwebpages.htm

The second NSF-sponsored project involved the armored storm penetration T-28 research aircraft operated by the South Dakota School of Mines and Technology. The T-28 was directed into thunderstorm echoes in real-time based on various color data displays available in the CSU-CHILL user van. These penetrations were designed to directly sample and identify the hydrometeor types present along the flight path. The in situ observations were then compared to the hydrometeor types inferred from the dual polarization radar measurements. The three dimension electric field measurements obtained by the T-28 were also quite useful for on-going storm electrification studies. The late July "monsoon" precipitation regime turned out to be quite active during the T-28 project, with storm penetrations being accomplished on each of five successive days. Comparisons between the hydrometeor types identified by the aircraft and the radar are continuing (see article on Page 6).

Four 20 hour projects were supported during the 2003 convective storm season. The first was a continuation of the convective initiation and thunderstorm gust front study under the directions of Profs. Bruce Lee and Cathy Finley, both of the University of Northern Colorado. The gust front observations involve shortening the duration of the CSU-CHILL transmitted pulse to .33 microseconds; yielding a range sampling resolution of 50 m [Fig. 1 (A) and (B)]. Although no particularly intense events were observed this season, several interesting data sets were collected. Most of the radar operations associated with the second 20 hour project involved polarimetric rainfall mapping studies conducted as a collaborative effort between Dr. Rob Cifelli of the CSU Department of Atmospheric Science and the National Weather Service Forecast Office in Boulder (Fig. 2). The radar rainfall estimations were calculated using several techniques based on a series of low elevation angle scans made at approximately four minute intervals. Correlations between the radar estimated rainfall and surface rain gage observations are currently underway. Particular analysis effort is being put into cases in which time-resolved rain gage data are available. The third 20 hour project was conducted for a group of several investigators lead by Dr. Jose Vanderlei Mar-

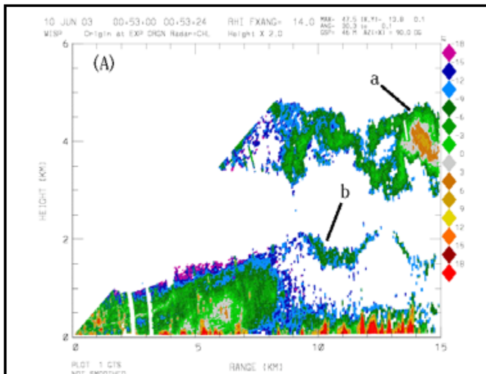


Fig. 1A. CSU-CHILL reflectivity RHI in 50 meter range resolution mode containing data collected during the UNC gust front 20 hour project. Visually, feature "a" was a non-precipitating mid-level cloud. Feature "b" is a wave structure on the top of a cold outflow airmass approaching the radar.

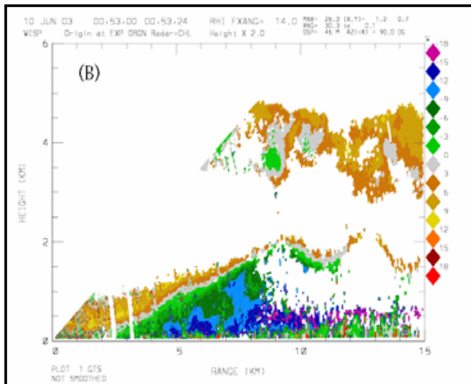


Fig. 1B. As in (A) except data field is radial velocity. Negative (inbound) velocities are associated with the outflow airmass.

Fig. 2. Leading portion of a thunderstorm cloud base observed from the CSU-CHILL Radar site near 6 p.m. local time on 10 June 2003. Radar scanning of the storms on this day was primarily done in support of the COMET 20 hour project.

2003 Operations Summary *(continued)*

tins (NASA). These researchers were operating several optical sensors at the summit of Mt. Evans. The optical sensors recorded various characteristics of the solar radiation that was back scattered from afternoon cloud systems located east of Mt. Evans. When interesting clouds were present, CSU-CHILL data were collected from a prescribed volume that enclosed the region viewed by the mountain top optical sensors. The precipitation particle characteristics inferred from the polarimetric radar data will be correlated with the optically-collected cloud observations. William Martin, a student from the South Dakota School of Mines and Technology, oversaw the fourth 20 hour project. In this work, oversampled time-series data from meteorological echoes were collected for statistical analyses.

Finally, target of opportunity radar operations were conducted during the early months of 2003 when no formal project support had been requested. During this period, an intense, widespread winter storm struck a large region centered on the eastern plains district of Colorado between 17 and 19 March. The onset of this storm was well forecast by the NWS, allowing both the CSU-CHILL and Pawnee radars to be staffed and operational before significant precipitation began to fall. The two radars began synchronized 360 degree PPI volume scans at 0114 UTC on 18 March (locally, 1914 MST on the evening of Monday, 17 March). Data collection ended slightly over two days later during the evening hours of Wednesday, 19 March.

Fig. 3. Picture of March 2003 snowfall taken in Fort Collins, CO.

Fig. 4. Extent of the snowfall observed at the CSU-CHILL Radar site on the morning of Wednesday, 19 March 2003. The bulk of the snow from the 17-19 March storm had fallen by this time.

Total snow accumulations in excess of 30 inches were relatively common in many areas along the eastern slopes of the Rocky Mountains (Fig. 3). In contrast, average snow accumulations were less than six inches at the CSU-CHILL site just northeast of Greeley (Fig. 4). An example dual-Doppler horizontal wind field synthesis is shown in Fig 5. At this time, a heavy snowband echo (green reflectivity colors) was located over Fort Collins (approximately 30 km west-northwest of the grid origin at the CSU-CHILL site). The airflow streamlines show the strongest wind speeds to be located in northerly barrier jet flow in the vicinity of the Fort Collins snow band. The CSU radar data sets will be useful in studying both the dynamic and precipitation microphysical aspects of this historic storm event.

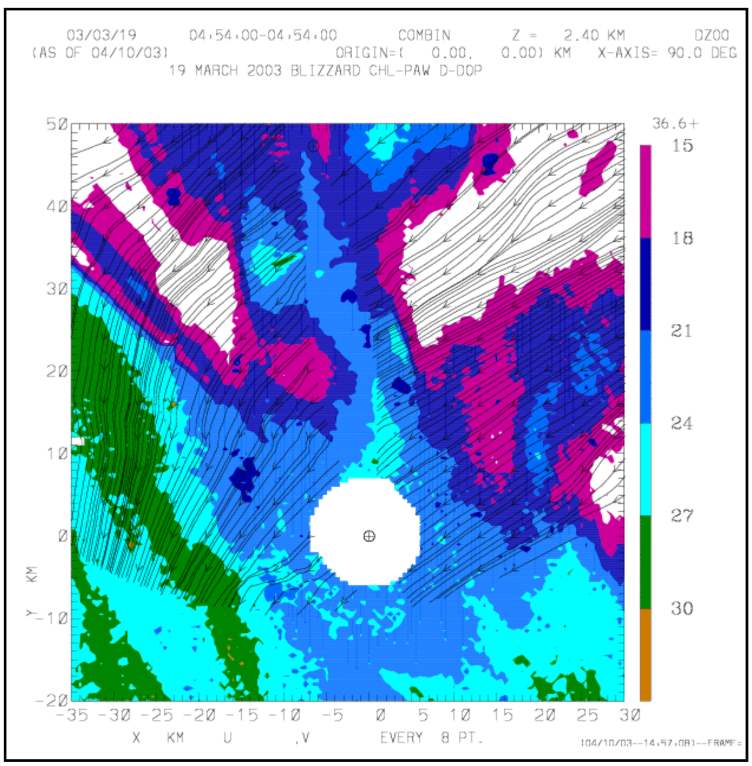


Fig. 5. CSU-CHILL and Pawnee radar dual-Doppler synthesis during the major winter storm of 1719 March 2003. The analysis height is 2.4 km MSL (~ 1km AGL). CSU-CHILL reflectivity levels (dBZ) are color-filled. Streamlines are earth-relative horizontal winds.

Applications Using the Polarimetric Covariance Matrix *(by Prof. V. N. Bringi & Yanting Wang)*

The CSU-CHILL radar is configured to measure the full 3×3 covariance matrix in real time with high accuracy. The Radar and Communication Group at CSU has been developing approaches for analysis of the full covariance matrix to estimate the microphysical retrieval such as mean shape and orientation, and further to correct the system errors, for example, in rain rate estimation.

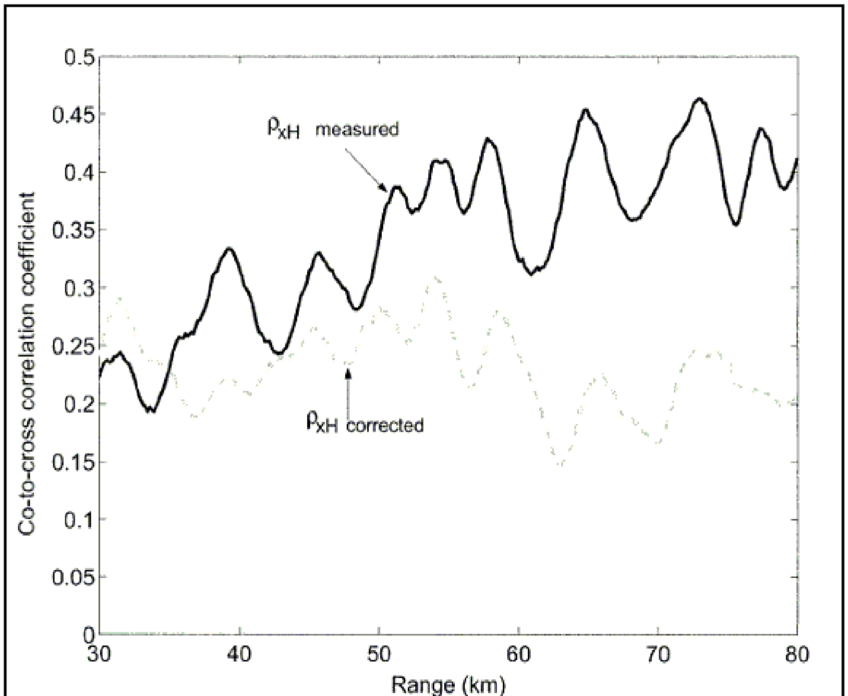


Fig. 1. Range profile of ρ_{xh} and polarization error corrected ρ_{xh}.

Hubbert and Bringi [1] proposed a methodology to estimate the antenna polarization errors based on the covariance matrix. It has been shown for rain drops that the mean canting angle β_0 is very close to zero, which means the propagation matrix is diagonal. Under such scenarios, both co-to-cross correlation coefficients, ρ_{xh} and ρ_{xv}, should tend to 0. However, if antenna polarization errors exist, a pair of effective tilt angles and ellipse angles may be induced which will cause cross coupling between the orthogonal polarization states and hence, increase ρ_{xh} and ρ_{xv}. Moreover, the effect of polarization error will be aggravated with Φ_{dp} increasing. Therefore, the ray profiles of ρ_{xh} and ρ_{xv} will show increase trend with Φ_{dp} if the antenna error exists. Tragl showed that $\rho_{xh}-\rho^*_{xv}=0$ under optimum polarization, which is the horizontal and vertical polarization for symmetric scattering medium with zero mean canting angle. By searching the minima in a reasonable range of tilt angles and ellipse angles, the antenna polarization error can be estimated. Figures 1 and 2 illustrate a heavy rain case from STEPS with the measured and corrected ρ_{xh} profile and *LDR* profile where the estimated polarization errors here are τ_h=-0.5, ε_h=-0.1, τ_v=89.5 and ε_v=0.4.

Once the covariance matrix is carefully calibrated and the possible antenna error has been corrected, attenuation correction can be applied and the propagation induced differential phase Φ_{dp} can be adjusted. Then the intrinsic backscattering covariance matrix is available. A simple basis transformation on the obtained covariance matrix to circular polarization basis was described in [2]. It has been known that the covariance matrix in circular basis presented separation in β_0 and ρ_4 from the size

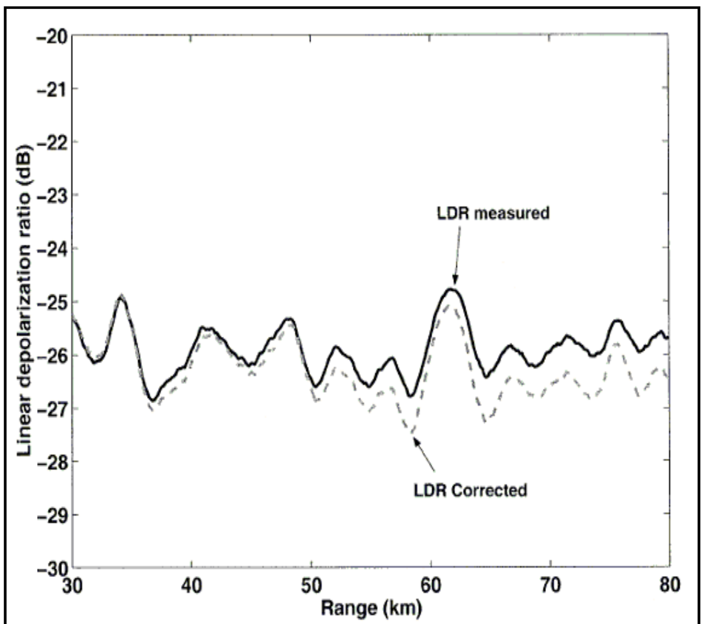


Fig. 2. Range profile of filtered *LDR* and polarization error corrected *LDR*.

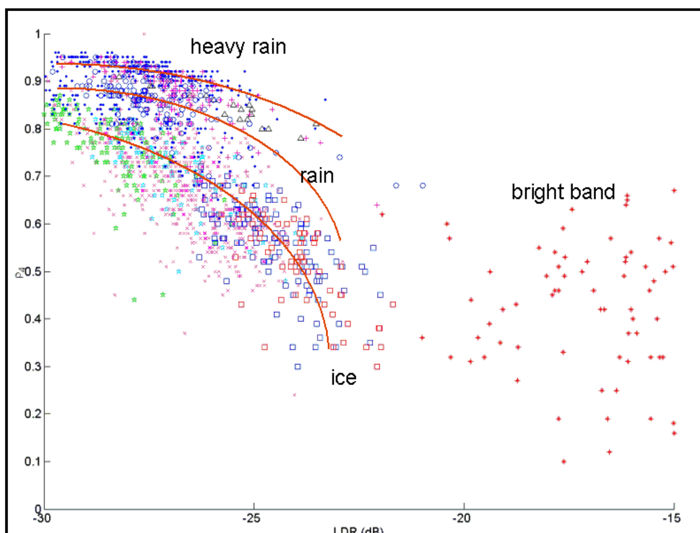


Fig. 3. Scatter plot of ρ_4 versus *LDR* with different types of storm.

Applications Using the Polarimetric Covariance Matrix *(continued)*

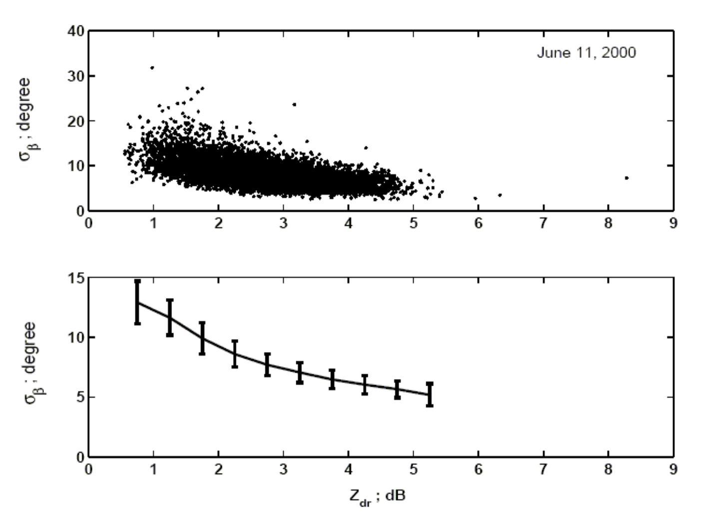


Fig. 4. Scatter and statistic plots of estimated σ_β versus Z_{DR} for an intense rain case.

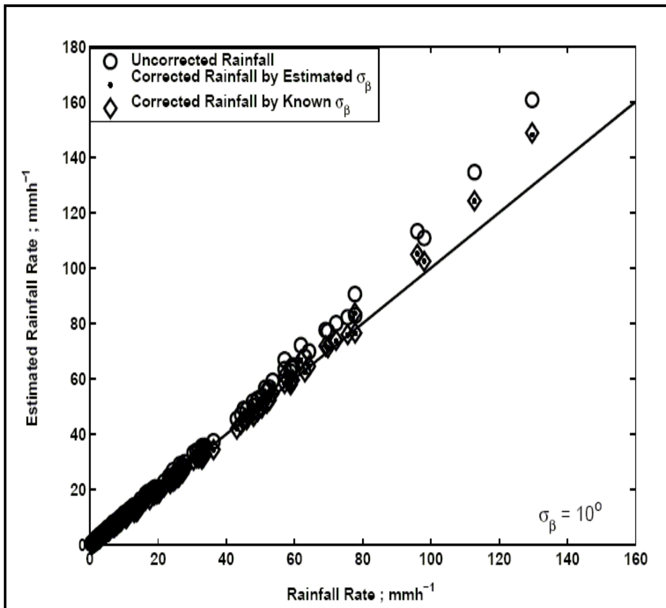


Fig. 5. The estimated rainfall versus "true" rainfall at σ_β=10°. The circle-marks are the uncorrected rainfall estimation, the dot-markers are the rainfall estimations corrected by estimated σ_β, and the diamond-marks are the rainfall estimation corrected by the known σ_β.

and shape information (note that ρ_4 is the orientation parameter defined by Hendry et al. from which the standard deviation of the canting angle is estimated assuming Gaussian shape). Specifically, β_0 can be derived from the phase difference between co-to-cross correlations in circular basis and ρ_4 is contained in the co-polar correlation coefficient. In practice, the antenna polarization error is fairly small for a well-tuned radar system. As long as such system error is negligible or corrected, the simple approach in [2] can be used to estimate the orientation factors easily just with a unitary transform. The estimated β_0 could be used to check whether system errors still exist. In addition, compared to *LDR*, which depends both on β_0 and ρ_4 as well as the axis ratio, the parameter ρ_4 has the potential to improve the hydrometeor classification. Figure 3 shows the comparison between *LDR* and the estimated ρ_4 collected from different types of storm events. Apparently ρ_4 illustrates a more clear separation over heavy rain, rain, and ice particle while *LDR* gives similar readings for most of them. This is very likely due to *LDR*'s dependency on the axis ratio.

When the mean canting angle β_0 is close to zero, which is generally true, the retrieval algorithm could be further simplified. Under such case, the co-to-cross correlation coefficients ρ_{xh} and ρ_{xv} are approximately zero. Huang et. al. [3] presented a simplified formula to directly estimate the dispersion ρ_4 from the power terms and ρ_{co} of the linear covariance matrix. The algorithm was applied to an intense rain event and assuming a Gaussian distributed canting angle its standard deviation σ_β was obtained. The result in Fig. 4 shows some finite spreading in canting exists probably due to transverse oscillations. Note that σ_β decreases as Z_{DR} increases which reflects the fact that larger drops are more 'resistant' to transverse oscillations (i.e., more stably oriented as compared to small-sized drops). Note that turbulence can cause a σ_β of < 5 degrees. Based on simulations, [3] also indicated the need to take account of the canting effect for intense rainfall. Within a traditional assumption (σ_β=10°) the drop canting can bias the rainfall up to 10% at higher rain rates. The results are illustrated in Fig. 5.

In summary, the full covariance matrix provides the possibility to estimate the orientation factors besides the size and shape information, which may be helpful to improve classification and further correct the rainfall estimation.

References:

[1] Hubbert, J. C., Bringi, V. N., 2003: Studies of the Polarimetric Covariance Matrix. Part II: Modeling and Polarization Errors. *J. of Atmos. and Oceanic Technol*, Vol.20, No.7, pp.1011–1022.

[2] Wang, Yanting, Bringi, V. N., and Hubbert, J. C., 2003: Transformation of the Polarimetric Covariance Matrix for Improving Hydrometeor Classification. Preprints, *31th Radar Meteorology Conf.*, Seattle, Amer. Meteor. Soc., pp.585–588.

[3] Huang, Gwo-Jong, Bringi, V. N., and Hubbert, J. C., 2003: An Algorithm for Estimating the Variance of the Canting Angle Distribution Using Polarimetric Covariance Matrix Data. Preprints, *31th Radar Meteorology Conf.*, Seattle, Amer. Meteor. Soc., pp.589–592.

Chill Facility Developments *(by David Brunkow, Senior Engineer)*

Real-Time Products

A system for the automatic generation of radar products was developed for the 2002 operational season. Procedures for polarization based rainfall accumulations and hail diagnosis products were installed at that time. For the 2003 season, two Particle Identification (Particle ID) products were installed. One was a fuzzy logic technique developed by Kyle Wiens at CSU-ATMOS. It was ported by Paul Hein from IDL to fortran-77, and routinely run on the lowest plane of the Cartesian grid produced as part of the rain algorithm. The Particle ID image was sent to our web site along with moment ppi/rhi images. This program was subsequently modified to run on all planes of the grid.

The second Particle ID product was the Neural Fuzzy system developed by Chandra et. al at CSU-ENGR. This also was routinely run on all planes of the Cartesian grid. It produced NCAR meta-code plots which could be viewed at the radar site.

Both of these products suffer from the difficulty of viewing the 3D grids generated over a series of time steps. Atmospheric Science graduate student Brenda Dolan is currently working on a system which will allow easier perusal of these near-real-time Cartesian data files from various sources, such as multiple radars. This viewing system is expected to be field tested in the 2004 data season.

Parallel Receiver

A second receiver was installed in the Fall of 2003. The analog 10 MHz IF signal was split just before the existing Lassen DRX digital receivers. Now the H and V IF channels are also routed to an ICS554 digital receiver card. This is a PMC card adapted to operate in the PCI bus of an Aspen (Supermicro) Linux computer. The card is equipped with two 14 bit 100 MHz analog to digital converters, and four Graychip (TI) digital receiver chips. These chips are used to perform the quadrature down conversion to baseband I/Q voltages. These samples are buffered and transferred to the computer memory for processing. In our case, the I/Q timeseries are gathered into blocks of 128 transmit pulses and 1000-5000 gates, and sent over gigabit Ethernet to one or more other servers where correlation processing and moment generation is done. Housekeeping information is supplied to this system via a serial port from the antenna controller. High speed azimuth and elevation information is decoded and supplied via a parallel port PCI card.

This system will be used to test signal processing ideas in a programmer friendly environment. It functions independently from the existing data processing and archiving system.

Antenna Upgrade

The CSU-CHILL antenna pedestal is undergoing some work in anticipation of the delivery of the new antenna in 2005. The servo drive motors, amplifiers, and controller will be replaced with a more modern and powerful system. The bulk of the assembly and development of this system will occur in 2004, but plans were made, and equipment purchases began in the Fall of 2003. The new system will involve a specialized control computer by Delta Tau. The motors will be permanent magnet brushless DC servos which will offer greater reliability than the conventional DC motors currently in use. The plan is to install the new drive system in the Winter/Spring of 2004 so that it can be fully checked out and operated for a season before the new antenna is installed.

Real Time Operation of Fuzzy Logic Hydrometeor Classification and Verification with T-28 in-situ Observations *(by Prof. V. Chandrasekar and Wanyu Li)*

The hydrometeor classification scheme developed for dual-polarization radars by Liu and Chandrasekar (2000) has been implemented at CSU-CHILL to run in real-time. This is continually being evaluated, where the performance of the algorithm is tested over a variety of storms, with feed back from users. From Jul 25th through Jul 30th of 2003, several "monsoon" events were observed in the northeast portion of Colorado. During this time, the T-28, the armored and instrumented research aircraft, flew coordinated flights. Experiments were conducted using both the CSU-CHILL and T-28 to collect in-situ observations over different parts of these storms. The following shows radar and in-situ data collected on the storm of July 26th, 2003. Figure 1 shows time series of T-28 in-situ observables, along with the 2DC images of particles for UTC time of 004220 to 004227. Figure 2 shows time series of T-28 in-situ observables, along with the HVPS (High Volume Particle Spectrometer) images of particles for UTC time of 004221 to 004222.

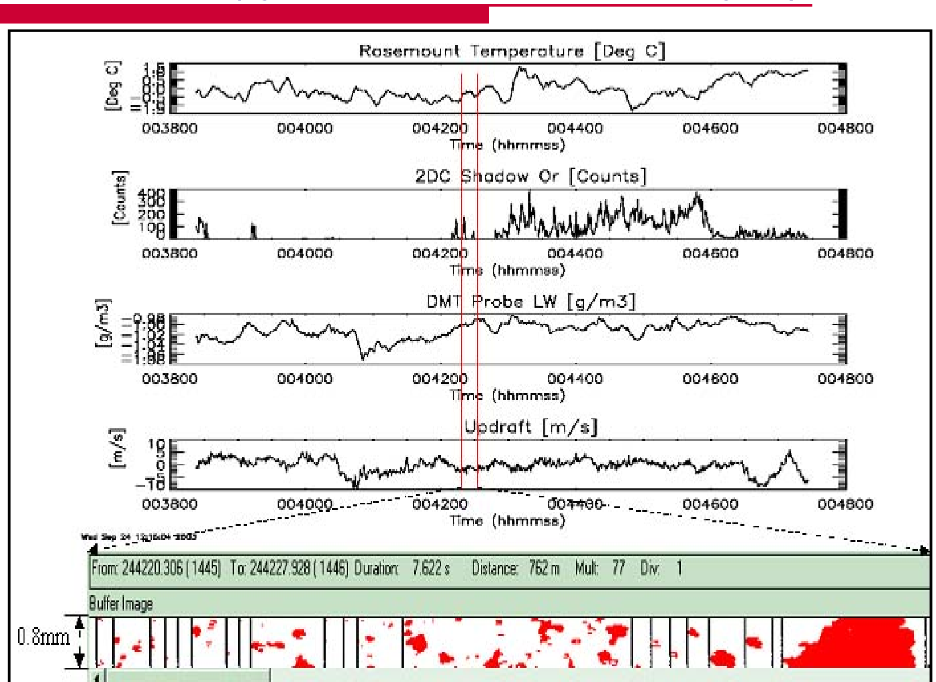


Fig. 1. T28 aircraft in-situ measurements. 2DC images shown on the bottom panel for the UTC time of 004220 to 004227.

Real Time Operation of Fuzzy Logic Hydrometeor Classification and Verification with T-28 in-situ Observations *(continued)*

The hydrometeor classification algorithm, which was running simultaneously on CSU-CHILL, indicated graupel or small hail on the T-28 track (during this time, T-28 was flying at altitude of 5km MSL) for the time period of 004220 to 004236. From the 2DC and HVPS images, it can be seen that the classification agrees with in-situ observations very well. Figure 3 and Fig. 4 show the reflectivity and hydrometeor type inferred for the region where T-28 was flying, at the same time period.

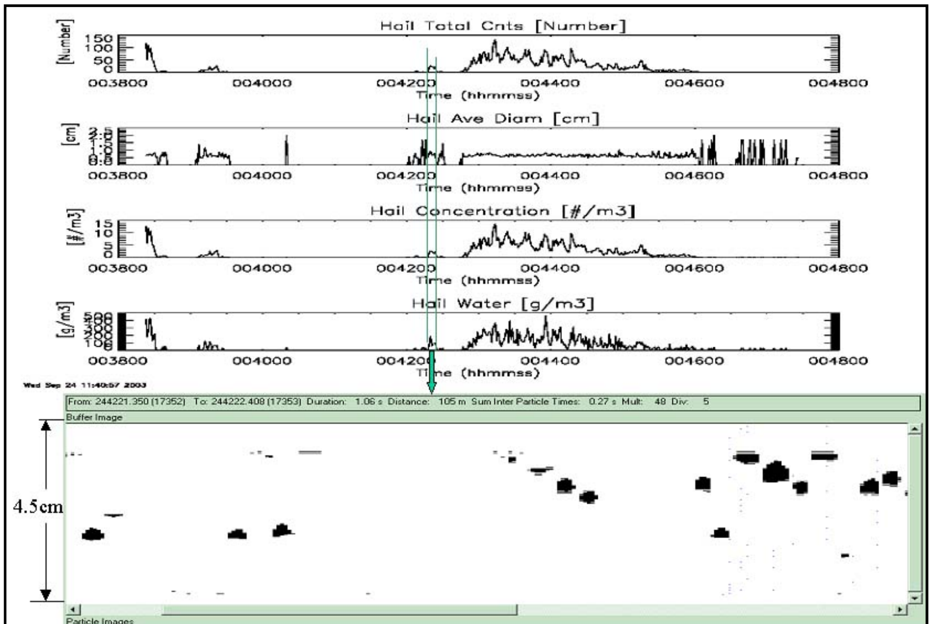


Fig. 2. T-28 aircraft in-situ measurements. HVPS images of particles shown on the bottom panel for the UTC time of 004221 to 004222.

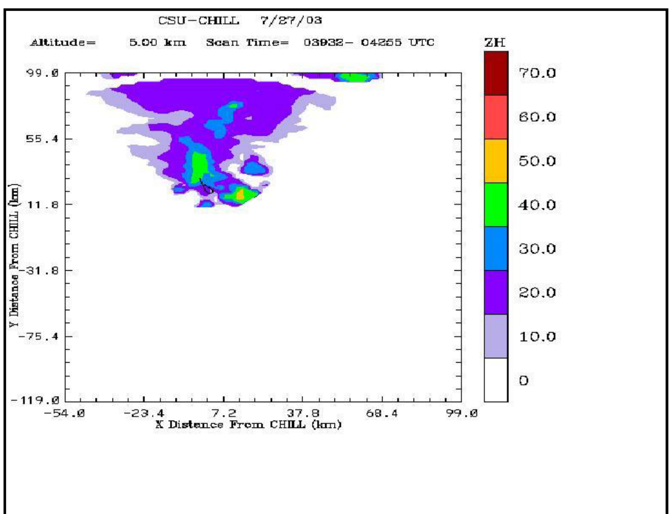


Fig 3. Reflectivity at altitude of 5km MSL shown with T-28 track for the UTC time of 003932 to 004255, July 27, 2003.

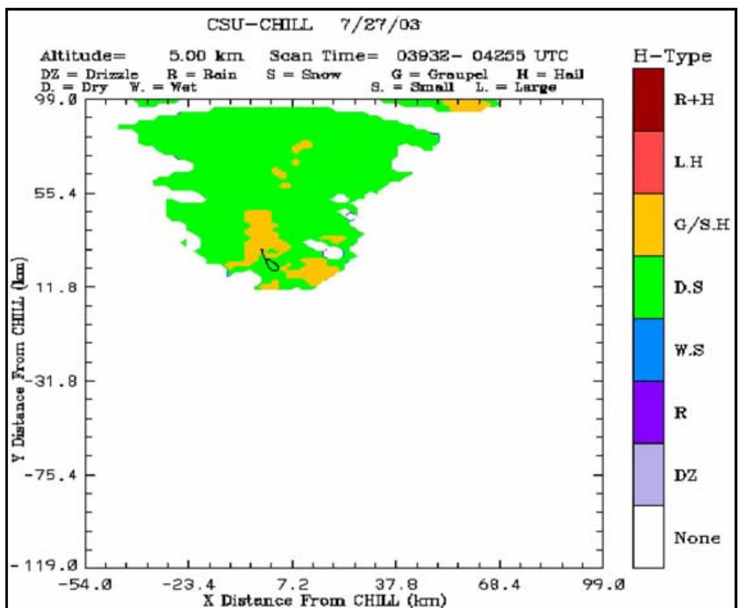
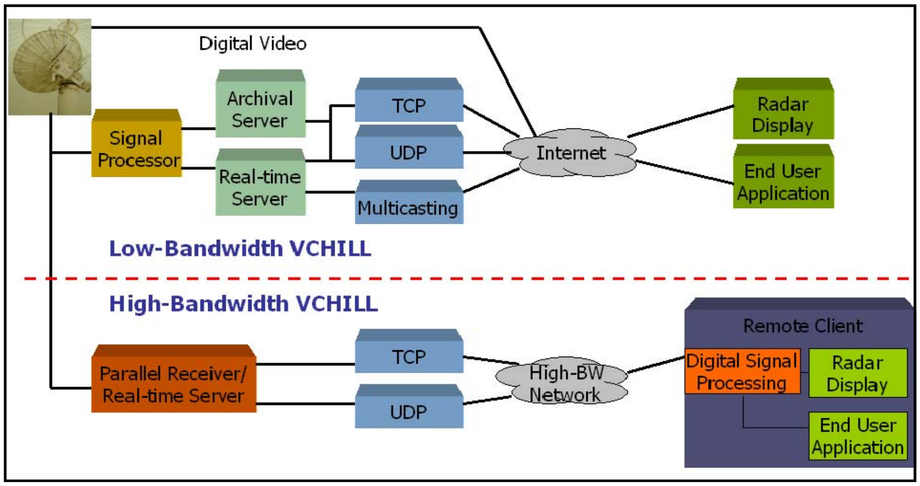


Fig.4. Hydrometeor Identification given by classification algorithm for altitude of 5km MSL shown with T-28 track for the time as in Fig. 3.

VCHILL—Virtual CSU-CHILL Radar *(by Prof. V. Chandrasekar and Yoong-Goog Cho)*

With the advent of data network technology, CSU initiated a project to enable the real-time operation of the CSU-CHILL radar over the Internet in 1997, which is called Virtual CHILL (V-CHILL). The goal of the project is to extend the educational and research experience of CSU-CHILL to remote locations. The V-CHILL has been implemented at several levels depending on the required bandwidth for the data transmission. The passive low-bandwidth V-CHILL is to transfer the radar observations to the remote sites for display and further end-user applications using Web pages with live updates. Data in this mode that has been in place for nearly 8 years has been used in numerous educational and research projects. The more advanced low-bandwidth application is an "active' mode, where the end users control the full radar operation over the Internet and the radar control is virtually transferred to a remote location. The high-bandwidth mode with V-CHILL is further sophisticated, which requires link capacity of a several hundred Mbps.



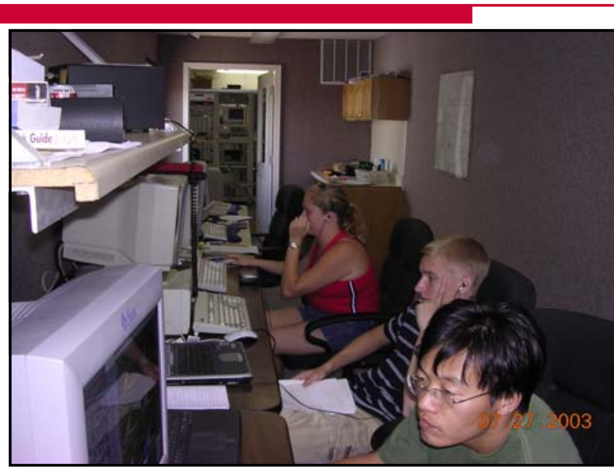
The low-bandwidth V-CHILL is being actively used by many universities over the United States as a part of radar classes during 2003. For example, in the classes instructed by Prof. Sandra Yuter of University of Washington (Instruments and Observations), Prof. Richard Orville of Texas A&M (Radar Meteorology), as well as Dr. Walt Peterson of University of Alabama, Huntsville (Radar Meteorology), students could figure out how the radar system operates by controlling the CSU-CHILL radar system remotely and displaying the various moments in real-time. These demonstrations were often accompanied by a live remote tour by Prof. Chandrasekar of CSU. The audio/video conferencing system was simultaneously used for communication between the CSU-CHILL radar site and the class. The AMS short course during the 31st Radar Conference in Seattle was developed totally using VCHILL, especially having the same impact as if the course was taught at CSU right at the radar site. The demonstration of the remote control the CSU-CHILL radar over the Internet and display greatly helped the students enhance their understanding on the principles and applications of weather radar system (based on the feedback). The practitioners in the Radar Conference participated in laboratory sessions working with VCHILL.

The high-bandwidth V-CHILL is the next level of providing the CHILL radar experience to the end user to the point it includes the signal processor and radar algorithms. It was experimentally validated on the test bed at CSU. The radar signals digitized using a parallel receiver are transferred to the remote sites over the Gigabit Ethernet. The main purpose is that different end users can apply different algorithms. This is primarily for graduate education and research applications. The radar parameters, such as reflectivity and velocity, are estimated in the remote sites and can be delivered to other nodes. Implementation of this application provides challenges, such as strict real-time requirements for manipulating digitized radar signal and signal processing, as well as variable latencies and deficiency of the available bandwidth for data transmission.

Output of the parallel receiver shows coincidence with that of the existing DRX system and the transmission rate is linearly proportional to the data rate of the parallel receiver. Currently experiments using high-bandwidth applications are being utilized by South Dakota School of Mines and Technology for fundamental radar signal studies.

Research Experience for Undergraduates Program, 2003
(by Prof. V. Chandrasekar and Wanyu Li)

During this past summer, CSU-CHILL hosted the annual Research Experience for Undergraduates (REU) program. This program's popularity and competitiveness has grown over its tenure at CSU. This session's class was comprised of 6 students who were selected from a pool of about 100 applicants. Among these, five students were drawn from out-of-state institutions and one from CSU. Dr. Chandrasekar, along with assistance from colleagues and group members, directed the six remote sensing related projects. The following describes two selected REU projects.



REU students working in CHILL user van with Dr. Wanyu Li .

Research Experience for Undergraduates Program, 2003 *(continued)*

Brian Eriksson, University of Wisconsin-Madison

Brian's project was titled "Virtual CHILL Real Time Control and Visualization Client.". The primary focus was to develop a program that would serve two functions:

-To be able to observe real-time data from the CSU-CHILL facility and have the data visually mapped out in standard formats.

-To remotely control the radar (i.e. elevation, azimuth, etc.).

REU student launching the calibration sphere (not seen) attached to the balloon.

Victoria Ting, University of Illinois

Victoria's project was titled "Real Time Evaluation of the Hydrometeor Classification Algorithm at CSU-CHILL". The main objective was to embed the hydrometeor classification algorithm into the radar real-time operation and archive the data of hydrometeor type for locations in the storm or that on the T-28 aircraft track, if available.

REU class of 2003: (top row from left) Victoria Ting, Kate McDonnell,, Carl Blake, and Adam Mihalik, (bottom row from left) Mike McClendon, and Brian Eriksson.

*For information on the REU 2004 summer program contact **Karen Bross (970-491-7275)** or access the following website:*

http://www.engr.colostate.edu/ece/pages/reu_main/index.html

CSU-CHILL Outreach Activities *(by Margi Cech, Research Coordinator)*

In addition to the many research activities pursued throughout the year, the CSU-CHILL Radar Facility also performs educational and scientific outreach activities as part of its mission. Some of these events, such as the VCHILL demonstrations and support for the REU program, have been described elsewhere in this newsletter. Other outreach activities conducted throughout the year include:

- During the Colorado State Science Fair, held in April each year at CSU, 13 high school students attended lectures and toured CHILL. Chris Rose, an EE Ph.D. candidate, hosted a tour of the CHILL for his former boss from the Los Alamos National Laboratory during this month, as well.

- In May, 14 undergraduate students enrolled in the University of Northern Colorado's radar class toured the facility and learned about on-going research, including several 20-hour projects conducted by the instructors (Profs. Bruce Lee and Cathy Finley). Later that month, four engineers from Ball Aerospace's phased array antenna design group also toured the facility.

- On two occasions during June and July, a total of 40 CoCoRaHS (Community Collaborative Rain and Hail Study) volunteers toured the CSU-CHILL Radar Facility and learned about the advanced capabilities of polarimetric radars. During one tour, the T-28 armored research aircraft operated by the South Dakota School of Mines and Technology was in town conducting NSF-sponsored research, and the volunteers were able to meet with the plane's pilots and lead scientists, and get a close-up look at the aircraft.

- During September, five students from Prof. Chandrasekar's undergraduate Electrical and Computer Engineering senior design class visited CHILL.

- During October, Prof. Chandrasekar arranged a CHILL tour for his colleague from the University of Puerto Rico, Prof. Sandra Cruz-Pol.

- In December, nine Atmospheric Science graduate students enrolled in AT650 (Measurement Systems and Theory), were accompanied to the CHILL by their instructor, Prof. Chris Kummerow, for an extended tour and lecture. In addition, Prof. Chandrasekar hosted a CHILL tour for Dr. Jim Kurose, a CASA project computer networking specialist who was visiting from the University of Massachusetts.

CoCoRaHS volunteers get a closer look at the T-28 armoured aircraft operated by the South Dakota School of Mines and Techology.

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CHILL staff host a visit from Dr. Sandra Cruz-Pol, University of Puerto Rico, during her December visit to Colorado State University.

New Antenna Update:

The contract for the new dual-offset Gregorian antenna was awarded to VertexRSI in June 2003. The preliminary design review took place 20-22 January 2004, at which time the mechanical design was also completed. Jack Fox of NCAR is assisting CSU in evaluating the mechanical design vis a vis the current pedestal. Dr. Ramanujam of Boeing is assisting in the evaluation of the electrical design. The critical design review is planned for June 2004, and range testing during February 2005. Final delivery of the new antenna is scheduled for no later than the end of March 2005.

Acknowledgements:

The CSU-CHILL Radar Facility is supported by NSF Cooperative Agreement ATM-0118021, and supplemented by cost sharing funds from Colorado State University.