QC869.4
.U6C6653
1994-7-6
ATMOS

Semiannual Report for

THE CSU-CHILL RADAR FACILITY

Cooperative Agreement No. ATM-8919080

Submitted to

LIBRARIES
AUG 08 2000
COLORADO STATE UNIVERSITY

The National Science Foundation

Division of Atmospheric Sciences

6 July 1994

DEPARTMENT OF ATMOSPHERIC SCIENCE
DEPARTMENT OF ELECTRICAL ENGINEERING
COLORADO STATE UNIVERSITY
FORT COLLINS, COLORADO

Semiannual Report for

THE CSU-CHILL RADAR FACILITY

Cooperative Agreement No. ATM-8919080

Submitted to

The National Science Foundation

Division of Atmospheric Sciences

6 July 1994

DEPARTMENT OF ATMOSPHERIC SCIENCE
DEPARTMENT OF ELECTRICAL ENGINEERING
COLORADO STATE UNIVERSITY
FORT COLLINS, COLORADO

QC 869.4
.U6 C6653
1994-7-6
ATMOS

TABLE OF CONTENTS

COLORADO STATE UNIV. LIBRARIES

1. Introduction

The following material constitutes the CSU-CHILL semi-annual report for the period 15 January to 15 July 1994. Highlights during this period include continued testing and verification of the superior performance of the new antenna system (installed in November 1993), commencement of the dual channel upgrade to the CHILL system, refurbishment of a recently acquired 45 foot trailer for shop and scientific work space, the support of numerous research projects, and the support of two projects focused on radar meteorology and radar engineering education. Also, funding for the fifth and last year of the present cooperative agreement with the NSF was received during this period. We are now preparing our proposal for the next five year cooperative agreement with the NSF.

On 8 April 1994 a formal meeting of the CSU-CHILL Radar Advisory Committee (RAC) was convened at the CSU-CHILL site. The RAC membership consists of Prof. Roger Wakimoto (UCLA), Prof. Pierre Julien (CSU-Civil Engineering), Prof. Bill Cotton (CSU-Atmospheric Science), Prof. Jorge Aunon (CSU, Electrical Engineering), Dr. Jeff Keeler (NCAR), and Dr. Dusan Zrnic (NOAA/NSSL). The all day meeting included presentations to the RAC on the new antenna (performance, acceptance testing, initial data collections), other system improvements including improvements to the receiver and synchro to digital conversion for antenna control, a lunch time presentation of in-house research activities, a discussion of the specific uses of the CSU-CHILL radar in education projects, and a detailed presentation and discussion of the dual transmitter-dual receiver upgrade now being implemented at CHILL. A formal report from the RAC on this meeting has been filed with the NSF/ATM. Letters from individual members of the RAC are included as Appendix A to this report.

2. Summary of Operations

The CSU-CHILL has been more or less continuously involved in data collection since late January. Operations are scheduled to continue until approximately 15 September 1994, when the transition of the radar to the two channel configuration will begin. Although most users have not had sufficient time to examine their data in detail, all indications are that the quality of the radar data has been adequate. Feedback letters received from users are included as Appendix B of this report. Table 1 summarizes projects that have been supported by the CSU-CHILL facility for the reporting period as well as one project that will be supported during late summer.

Table 1: CSU-CHILL Project Support Summary: January - September 1994

(* designates a 20 hour project)

Project	Dates	Scientific Objective
WISP94	1/25 to 3/25/94	Host of scientific objectives.
ACTS*	3/15 to 9/1/94	Radar documentation of cloud and precipitation conditions along a satellite to earth microwave propagation path. PI: V. N. Bringi
ANVILS*	5/1 to 6/30/94	Characterization of the evolution of radial velocity an hydrometeor fields in thunderstorm anvils. PI: J. Hallett
INSECTS*	5/24 to 6/7/94	Migratory patterns of Russian Wheat Aphids. Radar support of insect live capture flights made by U of Illinois helicopter. PI: T. Holtzer
REU94	6/7 to 8/19/94	Research Experience for Undergraduates project to expose 12 undergraduate engineering students to radar-related research activities. PI: V. Chandrasekar
SAILPLANE*	8/15 to 9/30/94	Use of CSU-CHILL to support the NCAR Explorer sailplane in gathering cloud electricity measurements. PI: D. Breed
FLOOD*	6/1 to 8/30/94	Investigation of WSR-88D rainfall estimation and hail identification algorithms using data from CHILL (multiparameter) and rain gage networks. PI's: V. N. Bringi, T. McKee
MCS94*	7/17 to 8/12/94	Documentation of upscale development of individual storms into MCS-sized systems. PI: W. Cotton

3. Educational Support

The CSU-CHILL facility continued to provide educational support during the current reporting period. Educational support at CSU was concentrated into two efforts: (1) The graduate level Radar Meteorology course offered at the Department of Atmospheric Science by Prof. Rutledge during the Spring 1994 semester (ATS 741), and (2) the Research Experience for Undergraduates (REU) project conducted during in the summer of 1994 by Prof. V. Chandrasekar of the CSU Department of Electrical Engineering.

ATS 741 had an enrollment of 8 students, seven from Atmospheric Science and one from Electrical Engineering. As part of the student course work, four case studies were analyzed by the students, working in groups of two. Data for the case studies were supplied by the CSU-CHILL radar. The reports generated by the students were also presented in class in a conference-style format. The case studies provide valuable hands on experience for the students. In analyzing the data, students work directly on workstations in the Department and use NCAR-developed software packages such as RDSS, REORDER, and CEDRIC. In addition to the data analysis exercises, the class also made two visits to the CHILL radar site to gain familiarity with the overall operation of the radar.

The REU94 program includes 12 undergraduate students from 6 states. These students are pursuing undergraduate degrees in several engineering specialties. The CSU-CHILL system is used as a demonstration of the application of a wide variety of engineering disciplines to the problem of research data collection with a meteorological radar (i.e. mechanical antenna drive and control systems, high powered microwave generation hardware, digital signal processing and the associated color display technology, etc.). To give the students a common foundation in radar meteorology, a series of one day lecture/demonstration presentations were conducted at the CSU-CHILL facility. An overview of these presentations is provided below:

Date	Presenter	Topic
6/9	P. Kennedy (CSU)	Introduction to radar meteorology
6/10	E. Mueller (CSU)	Introduction to the CSU-CHILL radar
6/14	C. Frush (NCAR)	Weather radar equation; radar design issues
6/15	J. Keeler (NCAR)	Digital signal processing for weather radars
6/16	F. Pratte (NCAR)	Radar calibration techniques
6/20	J. Turk (CSU)	Mu wave propagation; passive remote sensing
6/21	D. Breed (NCAR)	Overview on the NCAR Explorer sailplane
6/22	C. Mueller (NCAR)	Doppler radar applications to nowcasting
6/23	M. Politovich (NCAR)	Aviation safety applications of Doppler radar
6/24	M. Randall (NCAR)	Use of digital technology in radar receivers

4. Technical Developments

a. New Antenna Performance

The new antenna is performing well. Overall sidelobe improvements have resulted in less clutter contamination. The copolar correlation coefficient (ρ_{hv}) measurement has improved significantly due to a nearly constant phase difference pattern between H and V polarizations across the main lobe. This was recently measured using a test-horn transmitting 45° slant linear polarization, with the radar alternately measuring H and V polarized returns. At high elevation angles (>60°) in the stratiform region, the mean ρ_{hv} was measured in snow to be 0.996 with standard deviation of 3.44×10^{-3}. The standard ρ_{hv} estimator was used without any interpolation of the time-series data.

The ρ_{hv} measurement is particularly useful for identifying clutter, anomalous propagation, partial beam-blocking effects, and side-lobe generated artifacts in very strong gradient regions. It is also an excellent indicator of the base of the "bright-band" or melting level, and regions of rain mixed with ice (hail). Fig. 1 gives an example of a sample range profile of "raw" multiparameter variables Z_h, Z_{dr}, ρ_{hv} and ϕ_{dp} through a convective cell near Fort Collins known to have produced hail fall for around 30 minutes. While the well-known Z_{dr} hail signature is clearly evident between 44-49 km, a pronounced ρ_{hv} "dip" is visible centered at 49 km (and a smaller "dip" at 44 km). From theory, ρ_{hv} takes on local minima or "dips" whenever raindrops are mixed with hailstones. The rather low values of ~0.9 near 49 km is also suggestive of a wide range of non-uniformity in hail shapes. Surrounding the hailshaft, the ρ_{hv} increases to around 0.98. The ϕ_{dp} data shows an average K_{dp} of 0.83° km^{-1} (recall that elevation angle is 3° or altitude is 2.5 km agl which is near the 0°C level in Colorado).

Fig. 2 shows an example range profile of "raw" multiparameter data from a stratiform "bright-band" case very close to the radar. The "bright-band" is at range 4.25 km (altitude = 2 km agl). The ρ_{hv} "dip" centered at a range of 3.75 km (or, a few hundred meters below the "bright-band") denotes the base of the melting level and is nearly coincident with the positive Z_{dr} of 1.5-2.0 dB. Surrounding the "bright-band", the ρ_{hv} is very near to unity while ϕ_{dp} is "flat" with range as expected in very light rain. These two examples illustrate the performance of the new antenna, especially as related to the ρ_{hv} measurement. Of course, the new antenna has excellent cross-polarization patterns but an operational verification of the system LDR limit must await the implementation of the two transmitter/two receiver system. In spite of excellent main lobe pattern matching, close-in sidelobe mismatches occasionally produce artificial Z_{dr} signatures in high gradient regions of narrow hail cells depending on range. These are easily identified by the ρ_{hv} which rapidly falls to below 0.5 in such side-lobe contaminated regions and the Z_{dr} can easily be thresholded using the ρ_{hv} values. Because three-body scattering or hail "flares" also contaminate the Z_{dr} it is not clear that the artifacts are side-lobe or hail "flare" related. This topic is currently

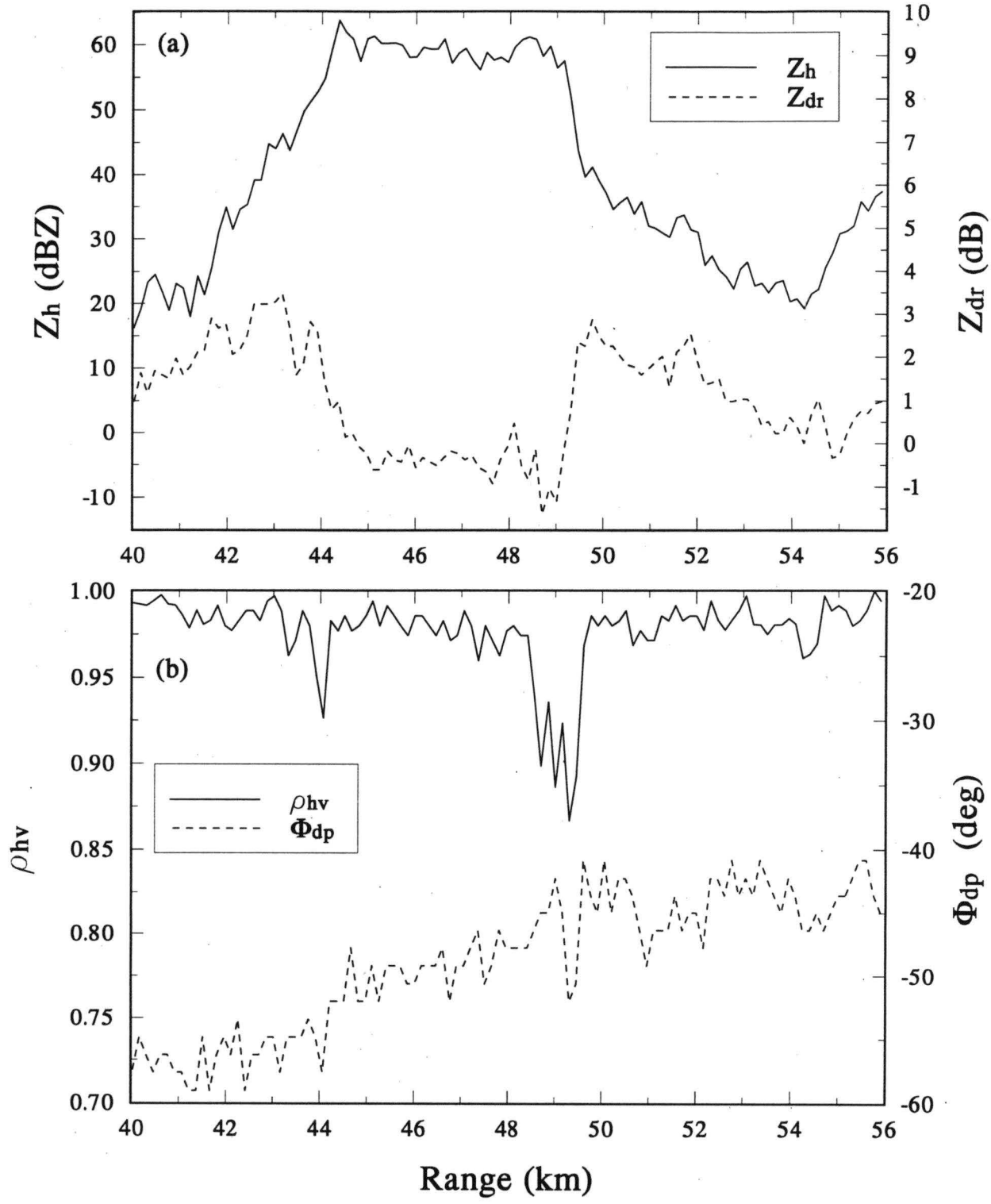

Fig. 1: Sample range profile of multiparameter variables in a hail cell located between 44 - 49 km range.

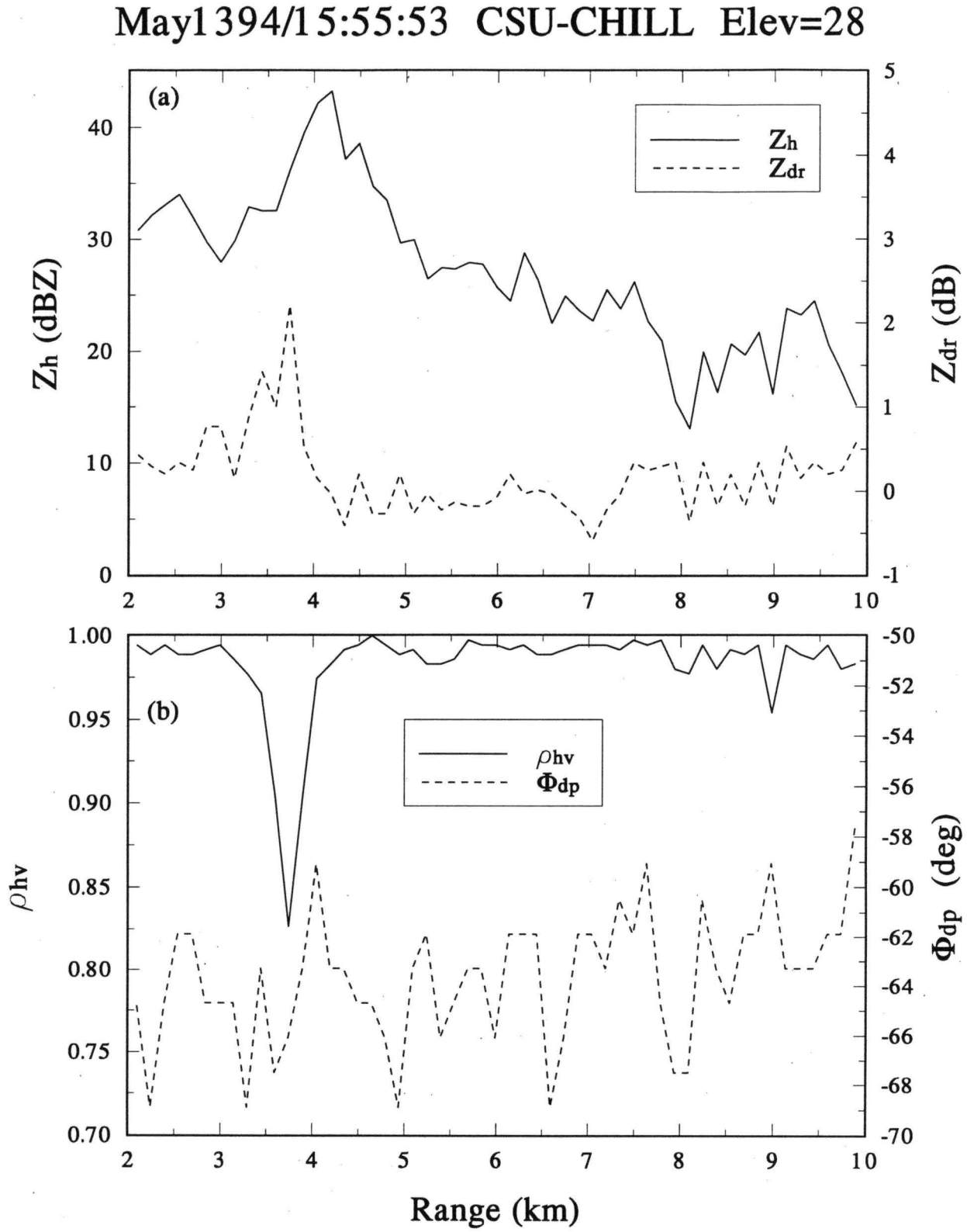

Fig. 2: Sample range profile of multiparameter variables through a bright-band located at 4 km range.

under investigation. Simulations will also be done on the ρ_{hv} reduction due to side-lobe contamination in strong gradients.

b. Dual Channel Transmitter Status and Van Upgrade

The development of a dual-transmitter, dual-receiver system for CHILL began in earnest during the reporting period. Many of the required electronic components for the second channel were obtained from the National Severe Storms Laboratory of the Environmental Science Laboratories of NOAA. These items provide the full transmitter for the second channel and some of the necessary electronics for implementing a second receiver. These items are as indicated in Table 2.

Table 2
Major Radar Items Obtained From NSSL

1. One (1) transmitter cabinets.
2. Two (2) high voltage power supplies.
3. One (1) water cooler.
4. One (1) induction regulator.
5. Distribution box.
6. Wave guide approximately 125 feet.
7. Wiring trough approximately 50 feet.
8. Wiring harness for at least one channel.
9. Preheat auto transformer.
10. Waveguide directional coupler.

These items have saved the project at least $100,000 as opposed to present day replacement costs. As time has permitted these items have been cleaned and individual parts checked. At this time the following parts have been checked and are operational as nearly as can ascertained.

1. High voltage power supply

a. The 5 kV supply has been solid stated with parts mostly obtained with the supply from NSSL. Power has been applied.

b. The 10 kV supply has been solid stated and power applied. However, there was a failure of one of the solid state rectifiers, which has now been replaced but full power has not been reapplied.

c. The focus coil power supply has been operated and is working properly.

2. The transmitter cabinet

a. The entire cabinet has been cleaned

b. The following diodes have been replaced with solid state diodes: the charging diode, the shunt diodes, the clipper diode, and the trigger amplifier charging diode.

c. The pulse transformer

i) The focus coil obtained from the Norman radar of NSSL was found to have a poor insulation to ground value. It has been changed for a focus coil that was on hand at CSU. There are few spares available for these focus coils (none at NCAR, possibly one at ISWS). In the past the CHILL system has had one rewound (total cost including new power supply ($15K). This might be kept in mind as we consider future budgets.

ii) The klystron obtained from NSSL is the wrong one for our operation frequency and will have to be replaced by one of our spares.

iii) The klystron base within the transformer obtained from NSSL was damaged and replaced by a spare that was on hand. New oil will be added when this is reassembled.

d. The cooling manifold has been disassembled, cleaned and new gaskets and washers installed.

e. The induction regulator has been checked for insulation values and appears to be all right.

Physical changes in the Configuration of CSU-CHILL

The addition of another channel has forced changes in the trailer space configuration. Until now the radar trailer has contained not only the transmitter and all of the high power equipment but also the data processing equipment. The data processing equipment will be moved to a new trailer that has been purchased. This will allow the second channel to be installed in the area formerly

occupied by the data processing equipment. The actual move of equipment will not take place until Fall 1994 due to the press of twenty hour research projects during the summer months.

When all of the equipment has been re-installed in their new places, the old user van will be abandoned. The old user van was an M-33 20-foot trailer with the running gear removed and installed on a flat bed trailer. This will be removed, but the flat bed trailer will still be a part of the CSU-CHILL system. Due to the larger radome, the more bulky packed antenna, and the need to carry the new Diesel generator, it has become necessary to have more room for traveling when a remote deployment becomes necessary. The additional space provided by the removal of the old user van may provide sufficient space to permit the deployment without any further need for additional trailer space.

A used 48 foot fully-insulated trailer was acquired to serve as the new user van and computer room for the facility. The trailer has a side door in the middle of the north wall which exits onto the existing deck and stairs serving the radar trailer. An interior wall divides the new trailer into a user operations area, and a machine room. The machine room will contain the computers needed for radar operations and the signal processing equipment. It will also be the location of a new UPS which was acquired to provide stable power for operation critical systems. A small work bench will be provided which will be the main electronics repair area when the system is on remote deployment.

The front 28 feet of the trailer contains the user operations area. This area provides up to 20 feet for tables to hold computer displays and terminals related to the radar, communications radios, and specialized equipment as needed for specific projects. This area also contains built-in storage cabinets and a kitchen area. Considerable effort was made to provide a quiet and comfortable work area for the users. Carpeting and other acoustical treatments were used to limit noise in this area. Two windows were installed to provide some contact with the outside world. A raised floor was installed throughout the trailer to provide heating/cooling ducts and a concealed wiring chase. New walls and ceiling surfaces were installed with 2 to 4 inches of additional insulation. Separate heating and air conditioning systems were provided for the two areas of the trailer with the provision of ganging them together to handle unusual situations.

The work on outfitting this trailer (new walls, floor, ceiling and electrical lighting and outlets) has been contracted to a local contractor and the expected completion date is mid-July.

5. List of Publications and Theses Using CSU-CHILL Data

Manuscripts Published or Accepted for Publication

1. Aydin, K., V. N. Bringi, and L. Liu, 1994: Rainrate estimation in the presence of hail using S-band specific differential phase and other radar parameters, accepted for publication in *J. Appl. Meteor.*

2. Bringi, V. N., L. Liu, P. C. Kennedy, and S. A. Rutledge, 1994: Dual multiparameter radar observations of intense convective storms: The 24 June 1992 case study. Accepted for publication in *J. Meteor. Atmos. Physics.*

3. Carey, L. D., and S. A. Rutledge, 1994: A multiparameter radar case study of the microphysical and kinematic evolution of a lightning producing storm. Accepted for publication in *J. Met. Atmos. Phys.*

4. Kennedy, P. C., and S. A. Rutledge, 1994: Dual-Doppler and Multiparameter Radar Observations of a Bow Echo Hailstorm. Accepted for publication in *Mon. Wea. Rev.*

5. Kennedy, P. C., N. E. Westcott, and R. W. Scott, 1994: Reply to the comments of C. A. Doswell III on "Single-Doppler Radar Observations of a Mini-Supercell Tornadic Thunderstorm". Accepted for publication in *Mon. Wea.. Rev.*

6. Rauber, R. M., M. K. Ramamurthy, and A. Tokay, 1994: Synoptic and mesoscale structure of a severe freezing rain event: The St. Valentine's Day ice storm. *Wea. and Forecasting*, **9**, 183-208.

Appendix A

Letters from members of the CSU-CHILL Radar Advisory Committee

UNIVERSITY OF CALIFORNIA, LOS ANGELES UCLA

BERKELEY · DAVIS · IRVINE · LOS ANGELES · RIVERSIDE · SAN DIEGO · SAN FRANCISCO · SANTA BARBARA · SANTA CRUZ

DEPARTMENT OF ATMOSPHERIC SCIENCES
405 HILGARD AVENUE
LOS ANGELES, CALIFORNIA 90024-1565
(310) 825-1751
OMNET: R.WAKIMOTO
INTERNET: ROGER @ CISK.ATMOS.UCLA.EDU
FAX: (310) 206-5219

April 9, 1994

Professor Steve Rutledge
Dept. of Atmospheric Sciences
Colorado State University
Fort Collins, CO 80523

Dear Steve,

This is my own follow-up letter concerning our recent RAC meeting at the CHILL site on 8 April 1994. It was a pleasure to hear and evaluate your accomplishments during the past year and over the entire duration of the Cooperative Agreement with NSF. CSU's record in maintaining and upgrading the radar as well as overseeing its implementation in research and education is a modern day success story. I have been especially impressed with the mileage you have attained with the 20-hr research projects. As a member of a competing university, I have to admit to be envious of your success. In fact, compared with NCAR, your facility has better served the university community as an educational tool. Moreover, you will soon have **the state-of-the-art multiparameter radar** that will be in exceedingly high demand as a research tool.

The following comments merely serve as minor suggestions that you should consider over the next few months:

1. In assessing CHILL's impact on education, I believe some attempts should be made to quantify its effectiveness There are various ways to do this -

    i. Soliciting written comments by the students during course evaluations specifically addressing the impact of the radar.

    ii. Tracking your graduate students to see if exposure to the CHILL radar made an impact in future job opportunities. This may be too early to implement now since your students have only recently used the radar.

    iii Comparing your graduate applications over the past few years to see if the quality (GRE and GPA scores) and quantity of entering students wishing to work in the area of radar meteorology has increased.

2. In the future, you should consider inviting high school teachers

to a workshop. This may be fairly simple if you coordinate with various UCAR programs. I believe Project LEARN invites teachers to Boulder, accordingly, you would only need to bus them up to Greeley for an all-day session.

I would also suggest that you advertise your 20-hr research projects at the upcoming UCAR Members' Reps/Heads & Chairs meeting in the Fall. You may also want to submit a short article to the UCAR Newsletter.

3. I agree with the rest of the RAC that an effective case has been made for a renewal of the 5-year Cooperative Agreement with NSF. I strongly endorse continued funding by NSF at approximately the same levels for the next 5-year agreement. NSF must be pleased with the commitment by CSU for significant cost-sharing (cash support estimated to be $100,000/year).

   For this next proposal, I recommend that the CHILL radar continue to collect high quality research and educational case studies in Colorado. However, to truly be a national facility and also to indoctrinate the radar as part of the fleet of high-quality research radars, future deployments in other geographic locations should be considered. In particular, I think there will be a growing demand by the microphysical community wishing to see the radar deployed in a semi-tropical climate to study warm-rain processes. Although the radar is more difficult to deploy, its unique capabilities should be tested at other sites.

I, again, wish to compliment you and your staff for the excellent job as caretakers of the CHILL radar. The joint efforts of the Departments of Electrical Engineering and Atmospheric Science are truly exemplary. You have convinced the community (and responded to any critics) that a national facility can be successfully maintained as a research and education tool at a major university. Good luck in your future endeavors.

Sincerely,

Roger

Roger M. Wakimoto
Professor of Meteorology

Colorado State University

Engineering Research Center
Foothills Campus
Fort Collins, Colorado 80523

April 11, 1994

Dr. Dusan Zrnic, Chairman
CSU-CHILL Radar Advisory Committee

Dear Dr. Zrnic:

Upon your request, it is my pleasure to report on the CSU-CHILL activities in the past four years, as we discussed last Friday in Greeley. I am very impressed with the on-going and past activities of the CSU-CHILL radar since it is located near Greeley.

The radar is operated by competent personnel. At least three faculty, Profs. Rutledge, Bringi and Chandrasekar, are working in close collaboration for the development and use of the facilities. Several post-docs and research associates complement the research programs. Hardware and software problems are also tackled by competent scientists such as Dr. Muller and Kennedy.

Most projects lead to refereed journal publications, which reflects on the top quality of the research. Several Ph.D. dissertations also centered on radar use and developments. The 20 hour projects are helpful for testing new initiatives and attract outside scientists.

The new antenna and upcoming dual channel capabilities should lead to significant technological improvements. The radar is a unique platform for testing Dr. Bringi's ϕ_{DP} precipitation algorithm. At Greeley, the radar is also uniquely located for the analysis of winter storms, severe thunderstorms in complex terrain, melting layer, and possibly tornadoes.

The budget is well-distributed among personnel, hardware and software. The CSU matching contribution is substantial and expected to be maintained. The resources are carefully used to optimize the scientific output of each component purchased.

In summary, I am impressed with the on-going and planned activities at the CSU-CHILL radar facility. There are true feelings of competence and friendly collaboration among research scientists that can only foster significant contributions to radar technology and atmospheric sciences.

Sincerely,

Pierre Julien

Pierre Y. Julien, Ph.D.
Assoc. Prof. of Civil Engineering

cc. S. Rutledge

Appendix B

Letters from users for projects supported from 15 January - 15 July 1994

NATIONAL CENTER FOR ATMOSPHERIC RESEARCH
RESEARCH APPLICATIONS PROGRAM
P.O. Box 3000 • Boulder, Colorado 80307-3000
Telephone: (303) 497-8488 • FAX: (303) 497-8401

6 May 1994

Dr. Stephen Rutledge
Department of Atmospheric Sciences
Colorado State University
Fort Collins, CO 80523

Dear Dr. ~~Rutledge~~ Steve:

WISP94 ended up being very successful with all the scientific objectives being achieved, with over 15 wave clouds and 20 winter storms being studied during the two month field effort. A large part of our success can be attributed to the excellent support provided by the CSU CHILL radar facility. Pat Kennedy and the rest of your support staff worked hard to make the project successful. CHILL was was ready for operations on the requested date, and collected data on nearly every storm studied during the project.

Thanks for your excellent support and I look forward to working with your staff in future field programs.

Best regards,

Roy M. Rasmussen

Roy M. Rasmussen
Chairman, WISP Scientific Steering Committee

The National Center for Atmospheric Research is operated by the University Corporation for Atmospheric Research under sponsorship of the National Science Foundation.
An Equal Opportunity/Affirmative Action Employer

Colorado State University

Department of Entomology
Fort Collins, Colorado 80523
(303) 491-7860
FAX: (303) 491-0564

July 06, 1994.

Pat Kennedy
CHILL Radar Site
Colorado State Univ.

Dear Pat

I'd like to thank the crew at CHILL for your asssistance with this year's Russian Wheat Aphid helicopter sampling. We've started to evaluate the insect material, and this year has turned out to be a sucess. We recovered RWA from a variety of altitudes and many of the atmospheric layers identified by the CHILL site. We have yet to complete the lipid anaylsis on all of the sampled individuals, but so far the results are quite promising with regard to publication.

We were impressed by the preformance of both the radar and the crew. We also greatly appreciate the CHILL crew coming in over the wekends, especially the Memorial Day Weekend. As you know, we were limited in the time we had for sampling, and the availability of the CHILL crew and equipment was very much appreciated.

The data from the radar runs was interesting for a number of reasons, and I'll be out this fall to further review some of it. I believe we may find some strong correlations between insect captures and certain atmospheric conditions we observed with the CHILL, especially the strong thermals we saw in the afternoons. I plan to present some of the data on the relationship of the observed atmospheric layers and aerial insect distribution at the National meeting of the Entomological Society of America this December. There will be at least two other presentations by CSU and University of Illinois researchers at the same meeting utilizing some aspects of the CHILL radar data.

Thanks again for all you assistance this year.

Sincerely,

Ian MacRae
Research Associate
Dept. of Entomology