The Research Experiences for Undergraduates Program: The 1995 Program at the Oklahoma Weather Center

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ABSTRACT

The 1995 Research Experiences for Undergraduates program at the Oklahoma Weather Center introduced 14 students to the rigor of meteorological research, as well as provided them with information to help make informed career decisions. A unique portion of the summer program was the students' participation in the 1995 Verification of the Origins of Tornadoes Experiment, in which they collected data on convective storms. Participation in the program exposed students to the logistics of a major field program and taught them about tornadic storms.

The program used a mentorship approach to teach the students how to conduct research. By working with a mentor, each student was exposed to the method of scientific research through direct interaction with a research scientist. An evaluation of the program found that it helped all students to develop confidence in their ability to do research and to be better educated about their career options.

1. Introduction

Scientists in the Oklahoma Weather Center[1] participated in a Research Experiences for Undergraduates (REU) program during the summer of 1995. Administration of this program, which incorporated an extensive field experiment, proved to be a formidable task. In this paper we describe how we planned, executed, and evaluated the 1995 REU program, with the hope that our experiences will help others who are considering or planning a similar program.

More than a decade ago, amid some concern about national productivity and global competitiveness, the National Science Foundation (NSF) established the REU program. The REU was one of several programs initiated to address various aspects of two suspected problems. The REU addressed a perceived impending shortage of research scientists, and it also addressed the lack of diversity in the scientific enterprise in the United States. While it now appears that there is a surplus of scientists in some fields, it is still true that most ethnic minorities in the United States, as well as women of all ethnic backgrounds, are greatly underrepresented in most scientific fields (Culotta 1992; Price and Hafer 1995). As with many programs started for one reason but continued for others, the REU program still addresses important national goals.

The NSF REU program is designed to develop an understanding of the process of scientific research among select undergraduates who stand to benefit most from the opportunity. The objective, as we see

[1] The Oklahoma Weather Center (OWC) is the name given to the group of federal, state, and University of Oklahoma organizations that work collectively on issues related to the earth's atmosphere. The OWC consists of the National Severe Storms Laboratory, the National Weather Service Forecast Office at Norman, the Oklahoma Climatological Survey (OCS), the University of Oklahoma (OU) Center for the Analysis and Prediction of Storms (CAPS), the OU Center for Computational Geosciences, the Cooperative Institute for Mesoscale Meteorological Studies, the OU Department of Geography, the OU School of Meteorology, the Storm Prediction Center (SPC), and the WSR-88D Operational Support Facility.

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In final form 27 June 1996.

it, is not to produce more scientists, but to produce both better research scientists and a better understanding of research among those who choose not to pursue a research career. We believe that, as we conducted it, the REU experience provided talented students a unique opportunity to get a better idea of what they might expect from a research career and thus be better informed to choose or reject it. Toward this end, we used the REU program as a matching process rather than an indoctrination process.

a. Historical perspective at the weather center

During the middle of the last decade, the leadership of the National Severe Storms Laboratory (NSSL) noticed a lack of young researchers entering the field of meteorology in general and severe storm meteorology in particular. Moreover, both local experience and statistics showed a lack of women and ethnic minorities in meteorology, especially at the Ph.D. level, and a lack of opportunities for students of both genders and all ethnic and economic backgrounds to be exposed to the process of meteorological research. Thus, NSSL supported one physics student from the University of Pennsylvania to work with NSSL scientists on a research project during the summer of 1987.

By the summer of 1990 the NSSL summer program had grown, with a total of 17 students participating in the program. [For a summary of the programs through the summer of 1990, see Lewis and Maddox (1991).] That summer 10 students spent 10–12 weeks in Norman, Oklahoma, and attended lectures on meteorology, performed experiments, worked on library projects, and participated in science mentorship projects. By the end of the program, students had received instruction in meteorology and exposure to meteorological research. Students remarked that this experience helped them to define their career options and personal goals more clearly.

Although the leadership at the NSSL considered the program a success, there were some logistical problems, including the limitations in financial support that a National Oceanic and Atmospheric Administration (NOAA) laboratory could offer. In response to these challenges and to expand the program, two scientists (B. Beasley and J. Lewis) in the Oklahoma Weather Center wrote a proposal to the NSF to conduct an REU program in the summer of 1991. This proposal was funded, with reviewers stressing the importance of providing travel and subsistence so that economically disadvantaged students could participate. In response to this suggestion, NSSL agreed to pay the stipend of several students, and the NSF grant covered the stipends of the rest of the students, plus travel and subsistence for all students.

Again with NSF support, scientists in the Oklahoma Weather Center held a similar REU program during the summer of 1992. Because of airline fare wars, the 1992 program ended with excess funds. These excess funds were used to support three students, who worked with the Cooperative Institute for Mesoscale Meteorological Studies (CIMMS) and NSSL during the summer of 1993, and to send two students to the REU run by the South Dakota School of Mines and Technology that summer. There was no summer program in 1994. In the fall of 1994, we proposed an REU site program for the spring and summer of 1995 as part of the Verification of the Origins of Rotation in Tornadoes Experiment (VORTEX; Rasmussen et al. 1994), a field program held in the central and southern Plains during the spring seasons of 1994 and 1995.

b. The 1995 REU

The 1995 REU program built upon the successful foundation of the previous programs. An important component of the 1995 program was the opportunity for students to participate in VORTEX field operations. This was planned as part of the REU program because of the perceived decline in interest in, opportunity for, and capability of students to participate in observational science programs at the undergraduate level. Moreover, experience from other REU programs (Arnhols and Woodley 1975; Orville and Knight 1992; Byrd et al. 1994) had suggested that student participation in a field project is a good method of maintaining and building interest in science. As VORTEX participants, students made field observations vital to the understanding of tornadoes and tornadic thunderstorms. This program provided them with the opportunity to learn about severe storms, observational instruments, program administration, and teamwork. In addition to participating in VORTEX, students worked with scientists in the meteorological research community and learned about the methods and procedures used in scientific research.

The 1995 program presented students with issues traditionally not discussed in summer programs, including special lectures on racial and gender discrimination, cultural differences, political issues, and ethics in science. Moreover, students received information about what to expect and how to succeed in graduate school. Our goal was to help these talented and qualified students make *informed* career decisions regardless of whether or not they chose to pursue a research career. In the following sections, we describe the program and some of the issues that we faced as we administered it.

2. The 1995 program

a. Preparation

Preparation for the 1995 program began in August 1994 with the writing and submission of the proposal to the NSF. When we learned that the proposal would be funded (January 1995), the REU committee, which consisted of two scientists from the NSSL (J. Cortinas and J. Schneider), two faculty members from the University of Oklahoma (OU) School of Meteorology (SoM) (B. Beasley and J. Straka), and an OU graduate student (C. Machacek), began to meet regularly. The graduate student served as general manager and was an important person in this and past REU programs. Our student manager was responsible for driving the students to and from their housing at the beginning and the end of every day. She distributed information to the students about daily activities, served as a 24-h contact in case of emergencies, and helped students with daily problems. She also played a key role in the organizational phase of the program since she offered a student's perspective on several key issues.

The REU committee's first challenge was to design the program in detail, taking into account the changing nature of science and technology in the 1990s. Issues addressed in these meetings included advertising the program, application requirements, participant selection, stipend amounts, transportation and housing arrangements, lecture topics, lecturers, tours, mentors, research topics, and arrangements for students to participate in the field observations.

Experience with previous programs taught us that advertising is a critical factor in determining the quality and quantity of applicants. In an attempt to reach a wide audience, we created a flyer that described the program and the application process and sent it to all member universities of the University Corporation for Atmospheric Research, Historically Black Colleges and Universities (HBCU), and the Hispanic Association of Colleges and Universities (HACU) (Fig. 1).

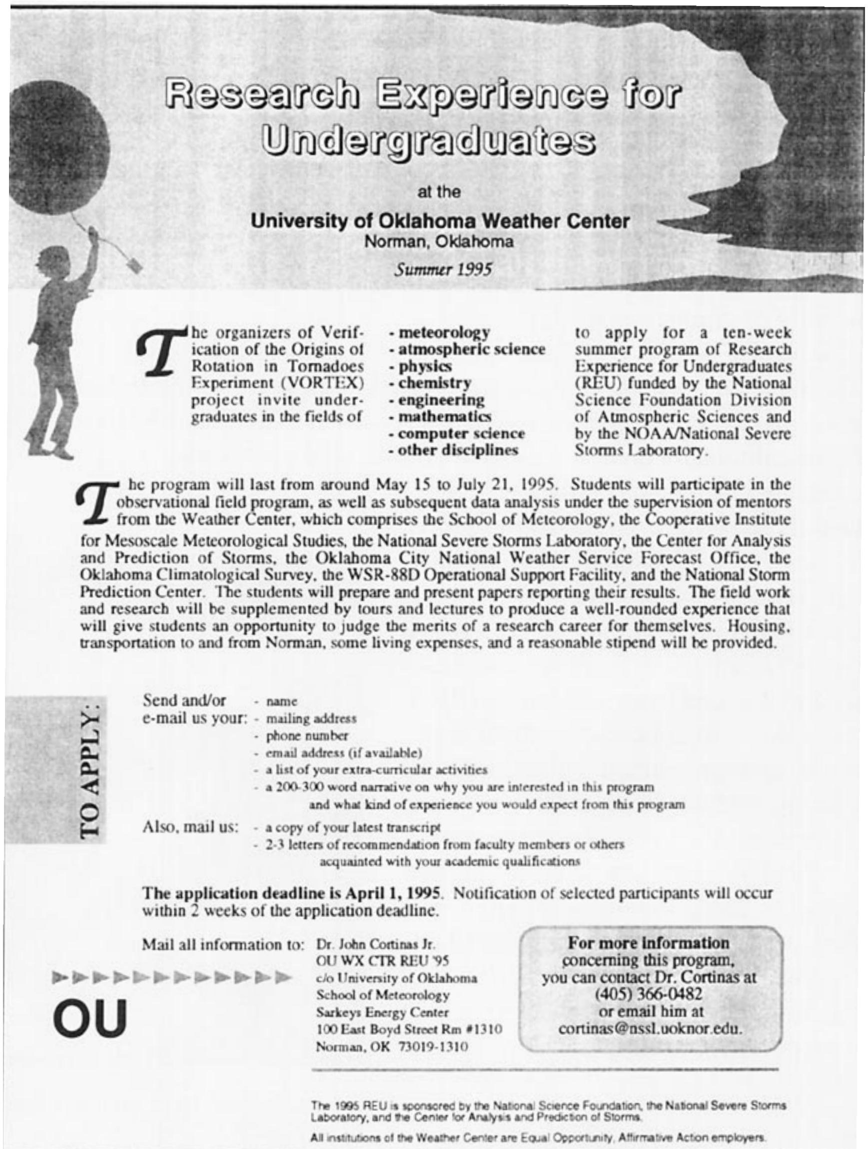

FIG. 1. Poster describing the 1995 Oklahoma Weather Center Research Experiences for Undergraduates program.

We also advertised through various electronic news groups that cater to students with meteorological interests and those of underrepresented groups in the sciences.[2]

We tried to devise an application process that would lead to serious applicants but would not be unnecessarily intimidating. We requested that each applicant submit

- a copy of his or her latest transcript,
- at least two letters of recommendation from faculty members or others acquainted with his or her academic qualifications,
- a list of extracurricular activities, and
- an essay of 200–300 words stating why he or she was interested in this program and what kind of experience he or she hoped to gain from it.

The application deadline was 1 April 1995. As in past Oklahoma Weather Center REU programs, nonmeteorology majors were allowed to apply since we felt that the REU experience benefits not only those students already committed to the atmospheric sciences, but also those in other scientific and engineering disciplines as well.

We received 67 complete application packages. The applicant pool was diverse with regard to gender, but as in past years, we received only a few applicants from traditionally underrepresented groups. Of the 49 males and 18 females, only 7 were from HBCU and none were from HACU. Although these are relatively small numbers, about 10% overall, they represent some progress as compared with previous years, in which there were virtually no applications from students in HBCU and HACU. It appears that there is still room for improvement with regard to attracting students from underrepresented groups into the atmospheric sciences.

The REU committee selected the participants, along with a list of alternates, first on the basis of scholarly merit and then with some attention to their potential to pursue graduate work (whether directly stated or not), apparent level of motivation, and potential to benefit from the REU. Letters of recommendation were crucial to this process since experience in graduate student recruiting suggests that grades are not always the best indicator of a person's interest and/or ability to conduct research. Within 2 weeks after the application deadline, we notified the selected participants by telephone and required them to accept or decline the offer within 1 week. Because of other commitments, 2 students declined our invitation and 2 alternates were selected, for a total of 14 participants, of which 2 were engineering majors and 1 was a physics major (Fig. 2).

The REU program provided each student with campus housing, transportation to and from Norman, daily transportation, and a stipend. Stipend amounts for the 10-week program were set at $3100 per student, which included a $60 weekly food allowance. After we decided on the application process and student stipends, we proceeded with organizing the main components of the program: the lectures, the student projects, and participation with VORTEX.

The REU committee selected lecturers from the Oklahoma Weather Center and collaborating scientists involved with VORTEX. We divided the lectures into "soft-scheduled" and "hard-scheduled" lectures because of the need to maintain flexibility with regard to participation in VORTEX field operations. Soft-scheduled lectures occurred during VORTEX on days when the field coordinator canceled operations. These

FIG. 2. The 1995 summer students and three of the administrators, J. Cortinas Jr., C. Machacek, and J. Schneider. Bottom row: C. Windler, J. Cortinas Jr., J. Schneider, M. Carr, and C. Machacek. Middle row: J. Weeks, C. Juckins, S. Butcher, and D. Geiszler. Top row: J. Pflasterer, E. Kemp, M. Richter, J. Ruthford, G. Bryan, P. Markowski, S. Overpeck, and O. Gibson.

[2] A page on the World Wide Web that described the program produced more than 500 inquiries from all across the United States.

lectures were primarily meteorological in nature, covering such diverse topics as field procedures, meteorological terminology, the planning of a field program, storm kinematics and morphology, research aircraft, radar theory, and flash floods.

Hard-scheduled lectures occurred after VORTEX. These lectures introduced the REU students to meteorological and nonmeteorological topics, which included tornadoes; severe storm forecasting; lightning; careers in research, operational, and private sector meteorology; experiences of an eminent scientist (D. Lilly); scientific presentations; technical writing; ethics and politics in science; affirmative action; cultural biases in learning; the NSF; and graduate school preparation. In all, we scheduled 28 lectures, each lasting roughly 1 h (Table 1).

Our single, most important consideration was that the REU program should provide the students with active and enthusiastic mentors. Starting several months in advance, we began inviting Weather Center scientists to participate as mentors. To be considered, a scientist had to propose a project that introduced a student to the basics of scientific research and could reasonably be completed in a 6-week period. The REU committee selected program mentors after assessing the project requirements of each proposal and determining if it was feasible for a student to complete the project.

Once the projects were selected, the REU committee assigned students to mentors by matching the students' interests, as stated in their essays, with the mentors' projects well in advance of the summer. We paid particular attention to providing a good match between student and mentor since we felt it was important for each student to be involved with a project that would capture his or her attention. Because of the diversity in student backgrounds and the requirements for the proposed projects, the matching process was not easy. Some projects required significant programming experience, while others required only experience in using spreadsheet programs. Furthermore, there were projects that required several semesters of meteorology, while others only required a basic physics course. In some cases, it was necessary to have a mentor adjust the project to accommodate the student's abilities. Eventually each mentor was paired with 1 or 2 students (Table 2).

Finally we tried to match the needs of VORTEX with the opportunities presented by the REU students. Deciding how the students would fit in with VORTEX was the principal responsibility of one of the authors (J. Straka), who was the assistant director for VORTEX. The committee decided that all the students would rotate through the tasks of assisting meteorologists in the operations center, collecting meteorological data near severe storms in mobile mesonet vehicles, flying in research aircraft near storms, and releasing balloons that carried rawinsondes into storms and their environments. After planning for 4 months, we were ready to implement the plan when students arrived around 15 May.

b. Execution

The 1995 REU program occurred in two very different phases because of the participation with the VORTEX field program. On the first day of the REU program, the students attended an afternoon seminar at which safety issues related to operations during VORTEX were discussed. It was extremely important for the students to understand the hazards involved with taking measurements near severe storms, and how to avoid them, before they participated in the field program. For the first 4 weeks of the REU, students attended daily (including Saturday and Sunday) weather briefings at 0915 Central Daylight Time (CDT). In these briefings, the meteorological situation was discussed in relation to the possibility of field operations for the day in question. A decision on whether field operations would take place was usually made by the VORTEX leadership by 1100 CDT. On operational days, students carried out their VORTEX assignments with little or no time to do anything else. On nonoperational days, students usually attended a soft-scheduled lecture and then were free to work with their mentors in the afternoon. The start of the REU program coincided with the start of the most active part of the storm season for VORTEX. As a result, students went into the field with VORTEX on their second day. This day ended as a success: the students and scientists associated with VORTEX collected an extraordinary amount of data on a tornadic supercell that produced four tornadoes!

The second phase of the program began after the final 4 weeks of the field stage of VORTEX. During this phase, students worked on their assigned research topics and attended hard-scheduled lectures. Students were encouraged to work independently, but to seek assistance from their mentors and other scientists when necessary. Usually students met with their mentors daily to report on their progress and to discuss any problems they had with their projects. This daily interaction appeared to help keep the students focused

Table 1. REU lectures.

Title	Lecturer	Affiliation
VORTEX Field Procedures and Field Safety Issues	J. Straka	SoM
Introduction to Weather Briefing Terminology	E. Rasmussen	NSSL
Planning a Field Program	E. Rasmussen	NSSL
Introduction to Storm Kinematics and Morphology	K. Droegemeier	SoM
Introduction to T-28 Research Aircraft	A. Detweiler	South Dakota School of Mines and Technology
The Problem with Water	J. Schneider	NSSL
Introduction to the National Science Foundation	S. Nelson	NSF
Introduction to the Department of Energy ARM Program	J. Schneider	NSSL
Introduction to WSR-88D Radars	D. Zrnic	NSSL
Aircraft and Profiler Radar Scanning Configurations	T. Shepherd and J. Schneider	NSSL
Introduction to Storm Thermodynamics	R. Davies-Jones	NSSL
Introduction to Thunderstorm Environments	M. Weisman	NCAR
Introduction to Flash Floods	H. Brooks	NSSL
Introduction to OU Mobile X-band Radar	J. Straka and J. Wurman	SoM
Introduction to Hail	C. Ziegler	NSSL
Introduction to Tornadoes	J. Snow and R. Davies-Jones	SoM and NSSL

and on schedule. At the end of each week, students met with the student manager and some of the committee members for discussions over lunch. These Friday meetings allowed students to discuss what had happened during the week, to bring up any problems they might have had with their research, and to compare notes and build camaraderie with the other students. At the end of the program, all the students were required to present a 45-min seminar on their research projects.

c. Student research

In keeping with our emphasis on scientific field work, all student projects involved the use of data collected in various field programs: VORTEX, Atmospheric Radiation Measurement (ARM), (Stokes and Schwartz 1994), Preliminary Regional Experiment for STORM (Cunning 1986), and the Oklahoma Mesonet (Brock et al. 1994). These projects exposed the students to working with raw data, giving them an opportunity to tackle real-world problems. At the end of the project, each student was required to write up his or her results in a format similar to that used in American Meteorological Society journals.

To illustrate the scope and the level of complexity involved in a typical REU project, we summarize two of them below. Both of these projects were of benefit to both the mentor and the student, and were projects in which the students learned about the process of research and at the same time contributed to the field of meteorology in a meaningful way.

TABLE 1. *Continued.*

Title	Lecturer	Affiliation
Forecasting Severe Weather using Radars	D. Burgess	WSR-88D Operational Support Facility
Introduction to Lightning	D. MacGorman and W. Beasley	NSSL and SoM
Introduction to Forecasting Severe Storms Using Numerical Weather Prediction	K. Droegemeier	SoM
Experiences of a Research Scientist	D. Lilly	SoM
Introduction to the UMASS and FM-CW Radars	H. Bluestein and D. Dowell	SoM
Scientific Ethics	C. Doswell III	NSSL
Affirmative Action	J. Jensen	OU
Introduction to Thunderstorm Morphology	E. Rasmussen	NSSL
Career Opportunities in the Private Sector	M. Smith	Weather Data, Inc.
Cultural Biases in Learning	J. Kanak	OU
Giving Audio Presentations	B. Forman	OU
Essentials of Technical Writing	D. Mair	OU
Careers in Research and Operational Meteorology	C. Doswell III	NSSL
Politics in Science	J. Kimpel	OU
Preparing for Graduate School	J. Schneider	NSSL

1) THUNDERSTORM ANALYSIS

This purpose of this project was to analyze and synthesize storm data from various platforms in order to gain some insight into the mechanisms responsible for tornadogenesis. The REU committee chose O. Gibson, a physics major with an emphasis in atmospheric science, to work on this project. His educational background and previous experience with computer programming made him a good candidate to work on this project. The data used in Gibson's project were collected during VORTEX with an Airborne Doppler Radar (ADR), mobile mesonet vehicles (Straka et al. 1996), and rawinsondes. Gibson was responsible for manually editing the ADR data and then synthesizing it with the mobile mesonet and rawinsonde data to create a three-dimensional depiction of a particular supercell sampled during VORTEX. Gibson edited the reflectivity and velocity data to remove ground clutter and other spurious echoes. Further editing of the aliased velocity values was required because of the relatively low (12.88 m s^{-1}) unambiguous velocity. Although the editing process was laborious, it provided an opportunity for Gibson to experience the process of preparing unedited field data for analysis. After synthesizing all the available data, Gibson and his mentors were able to produce a detailed view of a supercell thunderstorm that occurred on 29 April 1995 in northern Texas (Fig. 3).

The work of Gibson and his mentors provided a unique perspective on this particular supercell, which allowed them to form a hypothesis to explain why this supercell did not become tornadic. They speculated that the lack of a high correlation between the low-level vertical vorticity and the vertical velocity precluded the for-

TABLE 2. List of students and mentors in the REU program.

Participant	Affiliation, Year Completed	Title of Project	Mentor, Affiliation
G. Bryan	The Pennsylvania State University, Junior	Environmental Parameters Associated with the 17 April 1995 Tornadic Supercell	R. Johns, SPC
S. Butcher	University of Oklahoma, Junior	DEM-Based Pressure Reduction Technique	E. Rasmussen, NSSL
M. Carr	McGill University, Junior	Defining the Environment of a Supercell Storm	H. Brooks and C. Doswell III, NSSL
D. Geiszler	Texas A&M, Junior	Meteorological Observations of the 7 June 1994 Dryline	C. Ziegler, NSSL
O. Gibson	Clark Atlanta University, Junior	Multiple Platform Thunderstorm Analysis and Diagnosis Using Data Collected during VORTEX	J. Trapp, NSSL, and S. Lasher-Trapp, SoM
C. Juckins	State University of New York at Albany, Junior	Cloud-to-Ground Lightning Characteristics for Two Tornadic Supercells in the Texas Panhandle. Part I: the Friona/Dimmitt Texas Supercell	D. McGorman, NSSL and CIMMS
E. Kemp	Valparaiso University, Junior	An Analysis of the Advanced Regional Prediction System Forecasts for 7 May 1995	F. Carr, SoM, and K. Brewster, CAPS
P. Markowski	The Pennsylvania State University, Junior	Conserved Variable Analysis of PRESTORM Surface Data	D. Stensrud, NSSL
S. Overpeck	Creighton University, Sophomore	A Mesoscale Simulation of the 17 April 1995 Supercell Environment	J. Cortinas Jr., NSSL
J. Pflasterer	University of Oklahoma, Freshman	Improving Cloud Height Measurements	J. Schneider, NSSL, and M. Splitt, CIMMS/ARM
M. Richter	Purdue University, Sophomore	Numerically Simulated Storm Sensitivity to Various Storm Environments	A. Shapiro, CAPS, and J. Straka, SoM
J. Ruthford	University of Washington, Junior	Defining the Environment of a Supercell Storm	H. Brooks and C. Doswell III, NSSL
J. Week	South Dakota School of Mines and Technology, Junior	The Impact of the MCS of 7 August 1994 across Eastern Oklahoma	K. Crawford, OCS
C. Windler	University Of Oklahoma, Junior	Cloud-to-Ground Lightning Characteristics for Two Tornadic Supercells in the Texas Panhandles. Part II: The Kellerville/Allison Supercell	D. McGorman, NSSL and CIMMS

mation of a tornado (Trapp et al. 1996). The data synthesis process developed for this study proved to be quite useful for additional analyses of VORTEX storms.

2) THE SUPERCELL STORM ENVIRONMENT

The purpose of this project was to examine the near-storm environment and to determine if certain observed quantities, derived from wind and thermodynamic fields, can delineate between tornadogenesis and tornadogenesis failure. The REU committee chose M. Carr and J. Ruthford to work on this project. These students were meteorology majors with an interest in severe storms and some computer programming experience.

For this project, Carr and Ruthford obtained rawinsonde data collected over the VORTEX domain for 6 severe storm days and computed values of convective available potential energy (CAPE) and storm-relative environmental helicity (SREH) at each rawinsonde site where sufficient data were obtained. The most laborious task of this project was editing the rawinsonde data to remove errors determined by visual inspection. Although some of the errors were obvious, others were not (Fig. 4). When they felt that the data were questionable but the error was not obvious, they examined nearby rawinsonde data in order to justify any data editing. This eliminated some of the subjectivity associated with this process. After the data were edited, they examined the variability of CAPE and SREH within the severe storm environment by plotting the values of CAPE and SREH at each rawinsonde site within the VORTEX domain before and during the time that supercells were observed.

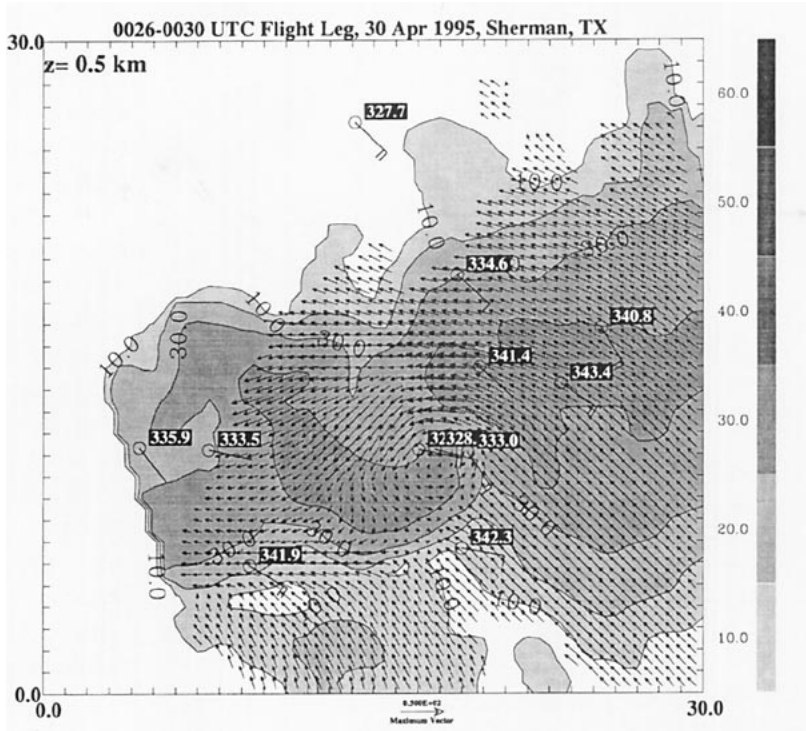

FIG. 3. Horizontal velocity vectors and radar reflectivity, at $z = 0.5$ km, for the 0026–0030 UTC flight leg on 30 April 1995 near Sherman/Dennison, Texas. Reflectivity is contoured every 10 dBZ, and vectors are storm relative. Surface mobile mesonet winds (a full barb is 10 m s^{-1}) and equivalent potential temperature (K) also are plotted. Origin is at 33.575° latitude and −96.85° longitude.

Plots of the CAPE and SREH data revealed an interesting aspect of the environment in which severe storms occurred. For example, strong gradients in the thermodynamic field, in particular the moisture field, characterized many of the severe storm environments that were examined (Brooks et al. 1996). These results support hypotheses developed over the last several years and contribute significantly to severe storm forecasting research since they address the questions of how the storm environment should be defined and which data should be used to assess the potential for storm development.

d. Evaluation

To evaluate how well the program met its objectives, to determine if there were parts of the program that could be improved, and to assess the immediate effects of the program on the students' views of their career options, we required each student to complete questionnaires at the beginning and the end of the program. The first questionnaire asked the students to discuss their postbaccalaureate plans, career plans, whether they considered themselves as potential research scientists, and their expectations of employment prospects. In addition to these questions, the second questionnaire contained questions related to the administration of the program. A comparison of the students' responses before and after the REU indicated that the program had an effect on some students with regard to their postbaccalaureate plans and their self-confidence in becoming a research scientist. The students' responses to the questionnaire given at the start of the program indicated that 11 students planned to attend graduate school, 1 student was unsure, and 2 students were not planning to attend graduate school. At the end of the program, the student that was unsure said that he then planned to attend graduate school, while the plans of the 2 students that did not want to attend graduate school remained unchanged. However, of those 2 students, one, a meteorology–broadcast double major, felt that her experience in the program reinforced her decision that

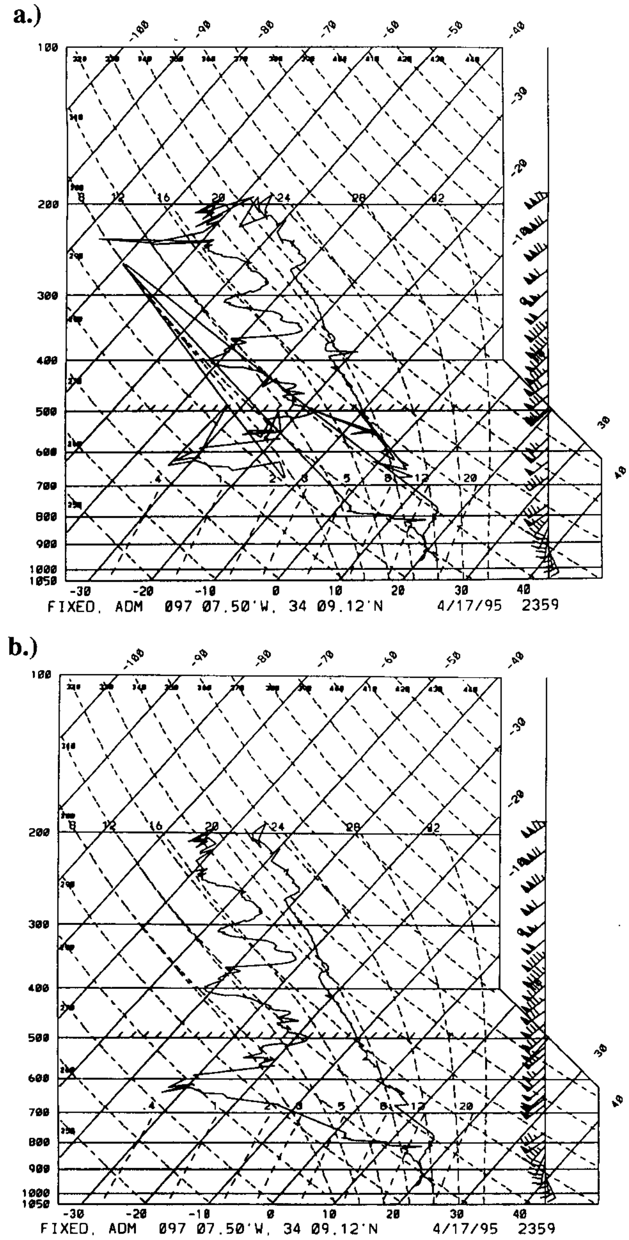

FIG. 4. Thermodynamic diagrams of (a) unedited and (b) edited temperature (°C), dewpoint temperature (°C), and wind (m s^{-1}) data from a balloon launched near 0000 UTC 18 April 1995 at Ardmore, Oklahoma.

graduate school was not part of her career plans, and the other student, an engineering major, felt that the REU experience had helped her to focus her interests on design rather than scientific research. We consider the decisions of these two students as positive outcomes in the sense that the experience helped the students to know themselves and their options better.

Most students did not have well-defined career plans beyond graduate school at the beginning of the program. Responses to the second questionnaire indicated that most students were still largely undecided about their career path but that several were seriously considering a career in research and that *they all felt better informed about their options.* When initially asked if they considered themselves potential research scientists, 7 responded yes, 4 were unsure, and 3 responded no. At the end of the program, 10 students responded yes, 1 was unsure, and 3 responded no. The change in students' perceptions of their potential to pursue research careers suggested to us that the REU program had a positive effect on the students.

The students' responses to the question of employment prospects indicated that most were unsure about the job outlook in their particular fields. Most students expected jobs to be available for scientists with an M.S. or Ph.D. degree but doubted that there would be very many positions for scientists with a B.S. degree. Some of the students felt that the current job outlook was bleak, but none of them felt so discouraged that they thought they should change majors.

The students' comments about the REU program itself were positive, and many were extremely positive. The words of one student capture the spirit of the responses.

> The strengths of the program were the variety of activities and educational opportunities and the outstanding support of (the scientists involved with the program) and the other (participating) scientists. I was made to feel very welcome at the (NSSL), which was something I was unsure about at first. This has been an overwhelmingly positive experience for me, probably one of the best times of my life. I would do it again in a second. I had REU at the top of my list of summer activities in March. If I had known how good it would be, it would have been the only thing on the list.

This is in line with exit-interview comments in previous years. One year, a student said he could not believe he had been paid to have so much fun.

It was clear from their comments that the students enjoyed their experience and learned much about a career as a research scientist. We realize, however, that evaluating any REU program is difficult and that any effective evaluation cannot be completed until the students have made some career decisions. Therefore, we will attempt to follow the students during the next decade as they progress through their careers.

3. Discussion

The 1995 Oklahoma Weather Center REU program was arguably the most successful yet at the Weather Center. We feel that our collective experiences from past programs contributed to the quality of this most recent program, in which we gained a greater appreciation of the complexity involved in coordinating a summer program with a field project. As in past programs, we concluded that the key to a successful program is the dedication of the people who organize it, administer it, and participate as mentors.

One of our objectives, and the main objective of the NSF REU program, is to give undergraduate students the experience of research. But, given 10 weeks during one summer, is it possible for students to obtain a reasonable research experience? The comments from the 1995 participants and mentors, along with an evaluation of the student reports, suggest that it is. Our evaluation indicates that all the students experienced several important components of the research process during the 10-week period: testing hypotheses, asking questions, developing and utilizing problem solving techniques, and communicating. We felt that by participating in the field experiment, as well as working with a mentor on nonideal problems, each student was offered a complete research experience. As in previous summer programs, using an apprenticeship approach to impart the research experience to the students was very effective, even in a short period of time.

This approach required a strong commitment from both the students and the mentors in order to be effective. Each mentor had to be available for most of the program to answer questions and to suggest ways of solving problems encountered with the research project. As expected, this commitment required a large portion of the mentors' time, with most mentors devoting between 40 and 80 h to the program. For those mentors that could not contribute a significant amount of time, comentors were established. The comentors worked together, sharing the responsibility of interacting with the REU student. We found that this concept worked well because it allowed each mentor more time to devote to their own research and to attend to other business during the summer. In addition to the assistance from the mentors, the students also enjoyed discussing their research results and problems among themselves at weekly meetings.

The Friday weekly meetings were one aspect of the 1995 REU program that we feel worked well. These meetings proved to be very effective in refining the students' interpersonal communication and problem solving skills. By discussing their problems in an open forum, the students often found that someone else had experienced a similar problem and already had a solution, or several students provided suggestions about how to solve the problem. Most of the students thought the Friday weekly meetings were helpful. One student commented, "if one of us needed something or wanted to ask something we had a friendly environment in which to do it." The exchange of ideas and solutions also taught the students the value of interacting with others to further their own research.

While most of the students' comments were positive, some of them suggested ways we could improve the program. The few issues with which we had some difficulty were soft-scheduled lectures, social gatherings, resources, and intercommunications. The soft-scheduled lectures were difficult to manage. The erratic weather-dependent schedule of VORTEX meant that some lectures had to be canceled because of time conflicts. Arguably, scheduling lectures during an active field project is probably not a good idea, but we felt that the few lectures by the out-of-town scientists collaborating with VORTEX were worthwhile for the students, and thus we considered them a partial success. These "down" days also were used to discuss student experiences and answer phenomenological questions that arose during previous operational days.

The intense activity of the first week of the program prevented us from having an early social gathering to introduce the students to each other, as had been done during previous programs. Some students suggested that such a gathering would have made them feel more comfortable with each other sooner rather than later.

Our high expectations of each student's performance required us to provide the optimal working environment for them. However, 14 students require a significant amount of working space and computer resources. We placed the students according to their mentors' locations in either the SoM or at the NSSL, and we provided them with computer accounts. Most students felt that this arrangement worked well. But this stretched our resources, and we would suggest careful evaluation of available space when deciding on the number of students that can be accommodated in any future program.

Finally, with five people in two separate locations involved with organizing and managing the program, we found intercommunication to be a challenge. At the beginning of the program, students were some-times unsure about whether and to whom they should report problems, but the student manager soon became the focal point. Some misunderstandings between committee members highlighted differences between their work cultures. However, we found that we could use these differences to our advantage. The benefits inherent in any large group allowed us to spread the workload among several people and to take over for one another if a scheduling conflict arose. Also, we felt that several different viewpoints were helpful when reconciling our ultimate decisions, even if it took time to reach them. We mention these issues to highlight the potential benefits and problems related to working with a committee in which responsibility is shared *equally* among its members.

The REU program not only gave students a valuable experience, but also provided the participating scientists with additional resources (namely, the students). Each project made a contribution to the field of meteorology, and several resulted in student coauthors of conference papers. Based on our cumulative experience with three NSF-supported REU site programs over the last 5 years, we recommend that any scientific group of reasonable size and appropriate commitment consider the possibility of hosting an REU, especially if field work can be incorporated.

Acknowledgments. Principle funding for this project was provided by the NSF under Grant ATM 9424209. Additional funding was provided by the NSSL, the Center for the Analysis and Prediction of Storms, CIMMS, and SoM. We thank Dr. Robert Maddox, director of the NSSL, for making laboratory resources available, Dr. Stephan Nelson at the NSF for his useful suggestions, Ms. Nancy Agrawal for her expert financial administration, the organizers of VORTEX for sharing their knowledge of field programs with the REU participants, the crews of the NOAA P-3 and the NCAR Electra for providing the unique experience of observing thunderstorms from aircraft, and the directors and managers of the Oklahoma Weather Center organizations for allowing the students to tour their facilities and work with their personnel. We extend special thanks to all mentors, scientists, and technicians of the Oklahoma Weather Center organization for the countless hours of helping these young scientists prepare for their future. Finally we would like to thank Drs. John Lewis and Robert Maddox for their foresight and wisdom in starting the first summer program for undergraduate students. Their dedication to the development of young scientists is most admirable and commendable.

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