An Example of a Research Experience for Undergraduates

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Abstract

This paper illustrates the planning and conduct of a Research Experience for Undergraduates (REU) project associated with the 1989 North Dakota Thunderstorm Project held in June/July of that year near Bismarck, North Dakota. This was a National Science Foundation/REU site award and required students from more than one school to participate. Ten students from seven schools were selected. They operated instruments on research aircraft, ran atmospheric sounding equipment, intercepted hailstorms and tested hailstone sensors, and coordinated Doppler radar data acquisition.

1. Introduction

A Research Experience for Undergraduates (REU) grant from the National Science Foundation was received by the South Dakota School of Mines and Technology to give students research experience during the North Dakota Thunderstorm Project (NDTP), conducted from 12 June to 22 July 1989. [Details of the project are given in a companion article by Boe et al. (1991).] Ten students were selected under the original grant; two students were added to the program by grants already in place at the South Dakota School of Mines and Technology (SDSM&T) and the University of North Dakota. Three other students participated to varying extents with support from the National Center for Atmospheric Research (NCAR). The primary purpose of the REU was to give the students exposure to, and experience in, meteorological field operations. Another purpose was to show by example how research is conducted in the field, and to allow the students to become familiar with the various equipment and instrumentation that are used in such experiments.

2. Recruitment and selection

A poster (Fig. 1) was prepared describing the proposed program, and mailed out at the end of January 1989 to more than 200 colleges and universities. Applications from students were received up until 7 March 1989, and selections were made by Nancy Knight and Harold Orville by 14 March. Ten students were selected out of 32 applicants.

The students were selected on the basis of their letters of application, their student status (graduate,[1] undergraduate), their primary interest, and their letters of support from faculty members. (A prior grant from the Division of the Engineering Directorate of the NSF, entitled "RUI: Hail Measurement—An Undergraduate Research Experiment," was used to support students in the design and construction of instrumentation that would measure the size and terminal velocity of hailstones in a time-resolved sense. Students from three schools, the South Dakota School of Mines and Technology, University of North Dakota, and South Dakota State University, participated in the hail sensor project. Some further testing and redesign of instruments is still ongoing, even though funds have long since been expended.) The hail sensor students were automatically selected, because of the previous work that had been done on the design and construction of the sensors and the fact that this field project was an opportunity to field test the instruments. The list of students selected for the REU, their year in school, and their academic major are listed in Table 1.

After the students were selected, they were given various administrative details, and arrangements were made for room and board at the Bismarck State College. It turned out that all the students desired accommodation at the college, which made housing quite convenient. The students were requested to report on 31 May, and to begin a short course 1 June concerning the field project and cloud physics topics.

3. Short course

A series of lectures and laboratories (Table 2) were prepared for the students that would familiarize them with the terminology and equipment with which they would be working. The seven days of lectures and

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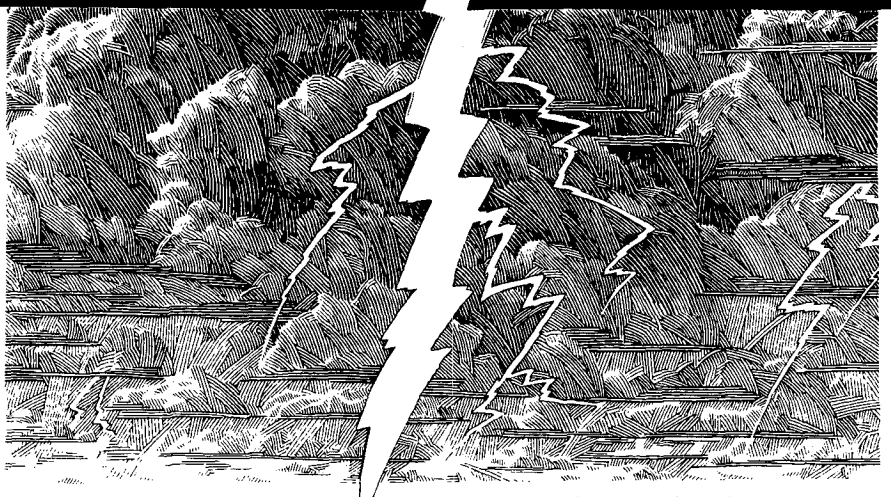
[1]A few graduate students were selected, because some of the funding came from general atmospheric science funding and not all from REU funds.

A SUMMER RESEARCH EXPERIENCE WORKING ON A THUNDERSTORM FIELD EXPERIMENT



Conducted by Scientists and Engineers from the South Dakota School of Mines and Technology (SDSM&T), University of North Dakota (UND), Several Other Universities, the National Oceanic and Atmospheric Administration (NOAA), the National Center for Atmospheric Research (NCAR), and the North Dakota Atmospheric Resource Board (NDARB) with support from the National Science Foundation

In the Bismarck, North Dakota, Region
31 May 1989 through 22 July 1989

THE PROGRAM

The North Dakota Thunderstorm Project to study the formation of rain and hail in convective storms is planned for the period 12 June to 22 July 1989 in the Bismarck, North Dakota, area. Several universities, NOAA, NCAR and private industry organizations are combining to deploy at least two Doppler radars, specially instrumented aircraft, one armored to penetrate severe storms, a few surface instruments, and atmospheric sounding equipment to sample the clouds and surrounding environment which lead to hail. Hailstorms create extensive damage in the Northern Plains and are still very difficult to forecast and a challenge to modify.

This summer program will involve ten undergraduate science and engineering students in the conduct of the experiment. Research experience will be available in (1) the development and testing of hail sensor equipment, (2) the operation of aircraft instruments and analysis of data which will involve flights around the storms, (3) the assistance in data gathering from radar and other ground equipment, (4) the operations of upper atmospheric sounding equipment, and (5) other possible jobs, such as assisting in setting out hail collectors and rain gauges and gathering rain and hailfall data.

ORGANIZATION

The summer student program is being organized and will be supervised by Ms. Nancy Knight of NCAR and Professor Harold Orville of SDSM&T. Many scientists and engineers from across the U.S. and some international scientists will be present during the field experiment and will be available for seminars and demonstrations of equipment.

Participants will be selected to assist in the taking of data and the conduct of the operations in the areas of interest mentioned above. A report of their experiences on the project will be required at the end of the project.

PARTICIPANTS AND SUPPORT

Participants are expected to be undergraduates in science, engineering, or mathematics and who have an interest in atmospheric or related science or in some engineering discipline applicable to the study of the atmosphere.

Each participant will be designated a student assistant and given salary support for eight weeks ($2,000). Reporting date is 31 May, final duty day is 22 July. SDSM&T will provide round trip commercial air transportation or auto mileage expenses to and from the field site, Bismarck, North Dakota. SDSM&T and the North Dakota Atmospheric Resource Board will assist in finding suitable housing and provide a housing and subsistence allowance.

APPLICATION PROCEDURE

Applicants should submit the following:

- A one-page statement describing the nature and depth of interest in the field project and plans for graduate school, if any.
- A letter of support from at least one faculty member at his/her home institution, with information about the student's academic record.
- Choices of three topics for the summer work, in order of priority, taken from the material above in paragraph 2.

The application material should be sent to:

Professor Harold D. Orville
IAS/Department of Meteorology
South Dakota School of Mines and Technology
501 East St. Joseph Street
Rapid City, SD 57701-3995

The deadline for receipt of applications and letters of recommendation is 7 March 1989. Selections will be announced by 15 March 1989.

The schools involved in this research welcome applications on behalf of all qualified science and engineering students, and strongly encourage women and minorities to apply. The opportunities for women and minorities in atmospheric and environmental sciences and supporting engineering fields are excellent. This project will give the students valuable field experience and should help in future employment possibilities.

FIG. 1. Poster describing a Research Experience for Undergraduates (REU), which was mailed out to more than 200 colleges and universities.

TABLE 1. List of REU students.

Student	Year in school	Academic major	School
Saleh Abudayyeh	Graduate	Mechanical Engineering	S.D. State
David E. Bixby	Senior	Meteorology	Iowa State University
Randall S. Collander	Junior	Meteorology/Mathematics	Metropolitan State College
Noma Kay Detweiler	Junior	Electrical Engineering	S.D. School of Mines and Technology
Paul A. Kucera	Junior	Meteorology	University of North Dakota
Todd R. Person	Senior	Electrical Engineering	S.D. School of Mines and Technology
Brenda M. Pobanz	Graduate	Meteorology	University of North Dakota
Olga Poulida	Graduate	Meteorology	University of Maryland
Ronald D. Rische	Junior/Senior	Electrical Engineering	S.D. School of Mines and Technology
William V. Shoemaker	Senior	Meteorology	Creighton University
Add-ons			
Wayland Collins*	Graduate	Meteorology	University of California, Los Angeles
Judy Moses**	Junior	Meteorology	Lyndon State
Edward Shyi-Wang Lin	Graduate	Computer Science	S.D. School of Mines and Technology
Craig Spriggs	Junior	Physics	Whitman University
Mike Walveart***	Senior	Meteorology	University of North Dakota

*Arrived 12 June **Arrived 3 June ***Arrived 6 June

laboratories were organized so that two lectures of one hour and twenty minutes each were presented in the morning and two laboratories were presented in the afternoons. Sometimes, two laboratories were combined to cover an extensive topic such as training on the Cross-chain LORAN Atmospheric Sounding System (CLASS) equipment or instruction in cardiopulmonary resuscitation (CPR). Three personal computers were made available to the students during the training sessions. In the afternoon laboratories, the computers were used for running programs that demonstrated thermodynamics and dynamic principles, and cloud physics processes, which were discussed in the morning lectures. Some of the laboratories involved movies of clouds, the formation of raindrops, and other pertinent topics.

The students were given the following material: 1) about 50 pages of text concerning the dynamics and thermodynamics of clouds (notes written by H. Orville and R. Farley); 2) copies of all transparencies used in the short course (more than 150 transparencies); 3) a PC floppy disk with programs to reproduce pseudo and saturated adiabats (for both liquid and ice process), to model parcel oscillations in a stable atmosphere, to demonstrate the activation of cloud condensation nuclei, and to simulate a one-dimensional, steady-state cloud; and 4) copies of all transparencies used by the guest lecturers.

4. Field project activities

The students had all been asked their job preference in the application process and were assigned specific tasks for their time on the project. Two students were assigned to the CLASS upper-air soundings, two to fly on research aircraft and operate scientific equipment, one to help in the radar operations in the operations center, and five on the three hail-chase teams. In addition, two other students, supported under other grants, were assigned to the hail-chase teams, so that seven students worked with the hail devices. Three students from NCAR's minority student summer program were assigned to aid in a cloud photography project under the supervision of Charles Knight.

In general, the students worked long hours and many days during a week. There were only three declared down days throughout the project, with several other days being partial down days. The students chased hailstorms as late as 2:00 A.M. on one "day." Unfortunately, the weather was not very cooperative and only about three viable hailstorm days occurred during the project, providing only a minimum amount of hail data. Nevertheless, other aspects of the program went very well and the students were extremely helpful in the project. The students helped in doing odd jobs for the project directors, such as taking helium out

TABLE 2. North Dakota Thunderstorm Project short course (Research Experience for Undergraduates).

Class Schedule	
Thursday, 1 June	
Lectures:	Introduction, administrative details, class organization, experimental design (H. Orville, N. Knight, B. Boe); experimental design, standard operating procedures, North Dakota storm climatology (B. Boe)
Labs:	Time-lapse movies of clouds, Hailswath I movie, Ice in the Atmopshere (NCAR) (H. Orville, N. Knight); visit to operations center and CP-3 radar (H. Orville, N. Knight)
Friday, 2 June	
Lectures:	Atmospheric stability, lapse rates, CCL, CCT, LCL, LFC (H. Orville); sawtooth approximation to pseudoadiabat, ice effects on cloud-lapse rates (H. Orville, N. Knight)
Labs:	BASIC programs for process lapse rates (Sawtoothl, WURT4) (H. Orville); hail sensors (Students, N. Knight, H. Orville)
Monday, 5, June	
Lectures:	Atmospheric dynamics—equations of motion, vertical motion equation, buoyancy; BASIC program for vertical motion—divergence, vorticity, synoptic-scale motions, continuity equation (H. Orville)
Labs:	Safety considerations, first aid training—CPR
Tuesday, 6 June	
Lectures:	Cloud physics—aerosols, CCN, IN, cloud characteristics and types, ice crystal types (H. Orville, N. Knight); condensation concepts, diffision growth equation, Kohler curves, collection efficiencies (H. Orville)
Labs:	CLOUD FORTRAN program (H. Orville); showed movies "Formation of Raindrops" and "Convection in the Atmosphere" (H. Orville, N. Knight)
Wednesday, 7 June	
Lectures:	Cloud physics—ice nucleation, diffusional and accretional growth, ice multiplication, hail, particle terminal velocities (H. Orville, N. Knight); Cloud-seeding concepts—microphysical and dynamic seeding concepts, modeling and observational results (H. Orville)
Labs:	Hailstorm chase simulation (N. Knight)
Evening	
Hangar cleanup	
Thursday, 8 June	
Lectures:	Severe storms, slide series (H. Orville); Numerical models of hailstorms, movie of modeling results (H. Orville)
Labs:	CLASS demonstration and instrumentation (NCAR personnel; Jerry Albright, Gary Wright, Chuck Wade)
Evening	
Hangar cleanup	
Friday, 9 June	
Lectures:	Radar (M. Hjelmfelt); microbursts (M. Hjelmfelt, H. Orville)
Labs:	Tornado slides, room cleanup, party (H. Orville, N. Knight, N. Hjelmfelt)

to the CLASS sites, picking up a radar cable from Watford City, and picking up dry ice for the project.

All of the students at one time or another were given a ride on the NOAA WP-3D cloud physics research aircraft. In addition, most of the students were able to observe the operations at the Mobile Operations Center for Control of Aircraft (MOCCA) site, and some visited a few of the other sites around the project. The

CLASS students had the most difficult jobs *with respect* to the time periods that they devoted to the project. Oftentimes, they would be out 12 hours or more a day; they had very little interaction with the other participants on the project. In the future, we would recommend a minimum of three students to be assigned for two CLASS sites so that the students could rotate through and see what else is going on during the project. We did not make such an arrangement on this project because there were not enough students to fill the jobs available.

The students were given a few additional lectures, one on the topic of cloud photography, one on atmospheric chemistry, and one on atmospheric electricity. These lectures were given by Charles Knight, Russ Dickerson, and John Helsdon, all experts in their fields.

The REU students were asked to evaluate the short course and their field project activities and were asked to write a short report concerning their summer's efforts. The verbatim responses to the evaluation form and the students' reports are available in the final report to the NSF, available from the meteorology department, SDSM&T. The evaluation form is shown in Table 3, and the responses summarized next.

5. Summary of student evaluations of the REU experience

Regarding the initial short course, 6 of the 10 students thought that the material presented in the lectures was appropriate. One student thought that the material was over his/her head and went into more detail than required. Others thought that portions of the material were beyond their comprehension. One said that the material helped him/her understand the weather briefings better, and another said the lectures helped him/her understand what the project was all about.

The students suggested other topics for lectures, such as aircraft instru-

TABLE 3. Evaluation questionnaire for REU-North Dakota Thunderstorm Project. (Responses to some of the questions are included.)

Initial short course

1. Was the material presented to you in the lectures appropriate?
2. What additional topics would you recommend for the lectures?
3. What were the most appropriate topics? least appropriate?
4. Were the laboratory topics appropriate?
5. Which were the most appropriate labs? least appropriate?
6. What additional laboratory topics would you suggest?

7. The lectures were:	SA	A	D	SD*
clear	4	6		
well organized	6	4		
understandable	3	7	1	
8. The visual aids were:				
clear	4	6	1	
understandable	2	9		
9. The written material was:				
clear	4	6	1	
well organized	5	4	1	1
understandable	3	5	3	
10. The laboratories were conducted successfully:	4	6	1	

Field Project

11. You were satisfied with your assigned duty.	SA	A	D	SD*
	8	3		
12. The additional lectures were helpful.	5	4		
Could not attend any.				
Does not apply; none were attended.				

13. If you were on another field project, what assignment would you prefer?
14. Additional lectures during the field project in the following topics would have been useful:

15. The following additional activities during the field project would have been appropriate:

*SA-Strongly agree; A-Agree; D-Disagree; SD-Strongly disagree.

	Excellent	Very Good	Good	Fair	Poor
16. Living conditions were:	1	2	4	4	
17. Food was:	1	2	5	3	

18. Things to add in a future project would be:
19. Things to avoid in a future project would be:
20. Any additional comments?

mentation, synoptic meteorology (to help the nonmeteorologist students understand the weather briefings better), more information on the development of the cloud models, slower-paced treatment of thunderstorms to allow more understanding, the forecasting of severe weather, and cloud seeding and hail suppression.

Concerning the most and least appropriate topics, the students highlighted cloud physics, radar, atmospheric stability and dynamics, formation of precipitation, cloud seeding, atmospheric electricity, and severe storms as the most appropriate topics. The approximations of the pseudoadiabat were mentioned as least appropriate.

The laboratory sessions were universally liked. The students thought the material in the laboratory exercises was easier to understand than in the lectures and they appreciated the opportunity to have hands-on experience. Some especially liked the computer simulation program.

There were differences of opinion regarding the most and least appropriate laboratories. The CLASS session was picked as both most and least appropriate. The visits to the operations center and to the radar site, the CPR training, hail-chase simulation, some of the movies, and the cloud model simulations were mentioned as being most appropriate.

A few additional laboratory topics were suggested. Aircraft tours, more computer simulations, more practice on hail intercept, more plotting of atmospheric soundings, and weather forecast simulation were recommended.

Regarding comments on the field project, most of the students seemed to be satisfied with their assignments, although more would have preferred to be involved with the airplanes.

The students appreciated the additional lectures during the field project. They suggested more lectures during the project on weather modification, severe-storm forecasting, project organization, how data are collected on the aircraft, and a lecture about opportunities in meteorology.

Concerning additional activities during the field project, the students suggested rotation of jobs during the project and more meetings among the students to see what each person had accomplished. Also, the CLASS operators wanted more opportunity to experience other aspects of the project.

The students had definite ideas about what to add in future projects. They wanted phones in their rooms, coed dorms, better communications, more principal investigator lectures to explain their involvement in the project and how they would use their data, more hail, more organized activities, more variety of jobs, extra CLASS operators, and more time to test the hail sensors.

Things to avoid in future projects, in their opinion, were pay phones, ground round, hail sensors that did not work, and North Dakota.

In general, the students were well pleased with their experience. One said the project "was probably the single greatest learning experience of my life."

6. Where are they now (Spring 1990)

Of the ten REU students, Saleh Abudayyeh is finishing graduate training at the University of Nebraska, Dave Bixby is in the NOAA Officer Corps, Randy Collander, Noma Detweiler, Paul Kucera, and Ron Rische are all finishing undergraduate college, Todd Person is working as an engineer in industry, Brenda Pobanz is in graduate school at the University of Wyoming, Olga Poulida is continuing graduate school at the University of Maryland, and William Shoemaker is a TV meteorologist in Omaha.

7. Concluding remarks

- We believe that this has been a very successful program. It has introduced students to observational meteorology and has piqued their interest in research and physical meteorology.
- Those who were not meteorology students have become interested in the atmospheric sciences, and it is hoped that they will continue on to graduate work with a greater awareness of things that can be accomplished in an observational science.
- The students helped in many different areas of the project and, at times, provided much needed labor. One of the aircraft hangars was cleared of debris by students and staff during two evenings of work before the field project began.
- Daily trips to the CLASS sites, each approximately 80 miles from the operational headquarters, and storm chasing, as well as transportation between various sites, exceeded the amount planned for vehicle use; the deficit was covered by funds from other grants.
- Graduating seniors should be eligible for REU funds. In some cases, these may be the students most easily convinced to go on to graduate school.
- Local colleges may be good for housing and food. In this case, Bismarck State College was a very convenient and economical choice for the students.
- All field programs, if at all appropriate, should have undergraduate and graduate student support.

[Hallett (1990) has reported on another research experience that involved graduate students only.]

Overall, we believe that this was an excellent experience for the students and was also a very good one for us. The direction of the students to the thunderstorms was done in an exemplary manner by Nancy Knight. The students learned to appreciate her expertise in directing them to the possible location of hailfall.

Acknowledgments. The leaders of the North Dakota Thunderstorm Project were extremely helpful and cooperative, particularly Mr. Bruce Boe, director of the North Dakota Atmospheric Resource Board. Mr. Jim Jung, also of the board, loaned us his own computer. All project personnel were very cooperative and helped the students in many ways.

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