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## 1. INTRODUCTION

The Department of Energy, Office of Science's Climate and Environmental Sciences Division (CESD) has supported undergraduate and graduate education in climate change research through the Global Change Education Program (GCEP) since 1999. CESD informally assessed the work force in climate researchers, especially climate modelers and found that a larger portion of its researchers were approaching retirement stages of their careers. GCEP endeavored to address the deficiency by replenishing the field with new talented researchers.

GCEP supports two programs: The Summer Undergraduate Research Experience (SURE) and the Graduate Research Environmental Fellows (GREF) programs. Students are mentored and contribute directly to ongoing climate change research in atmospheric science (clouds and aerosols), climate modeling, terrestrial ecology, and carbon cycles. Complete details on the program can be found at <http://www.atmos.anl.gov/GCEP/>

This paper outlines the lessons learned from the design and management of this program over the 12 year period since its inception and focuses on its key aspects, including an annual Student Orientation and Final Workshop, and the GCEP mentoring process. GCEP has worked to maintain a growth experience for SURE in order to encourage the completion of B.A. and B.S. degrees and subsequent entrance into graduate schools, and for GREF to encourage the completion of graduate degrees (primarily Ph.D.) in the areas of climate change. The coordination of mentoring activities is discussed and data presented showing the success of the GCEP program in increasing the number of U.S. graduate students and in producing quality climate change researchers in workforce development. The importance of continuing GCEP alumni contact and support via career counseling and reference letters and an internet alumni page, and also encouraging past GCEP alumni to serve as mentors themselves is stressed.

Other lessons learned from the past 12 years of managing the SURE and GREF programs are discussed, with particular emphasis on the importance and effectiveness of having the students contribute directly to the research effort in climate change.

This is clearly demonstrated by the number of peer-reviewed papers and presentations at national meetings that have been co-authored by GCEP students. Focused mentoring is key to this effort and is highly recommended in climate change education efforts and fellowships.

## 2. FOCUSED MENTORING IN CLIMATE CHANGE

The heart and soul of the GCEP program is its mentors and students. Making connections between students and suitable mentors is key to the success of both SURE and GREF students. Students are connected with mentors and research projects that they are both prepared for academically and also have a keen interest in pursuing. This assures that both mentors and students benefit from the interactions.

The SURE students in GCEP are selected for their academic abilities and their research interests as evaluated from their transcripts, reference letters, and from a written statement of goals that includes their specific climate change areas of interest. A panel review process is used for the selection of students interested in a broad range of climate change areas including atmospheric science (physics and chemistry), terrestrial ecology (biology), soil science and ecosystem research (microbiology as well as chemistry and physics, and climate modeling (math and computational skills). This necessitates having an interdisciplinary team of reviewers from the various areas of climate change research supported by the DOE's Climate Change Research program in Biological and Environmental Research.

Once the SURE students are selected, they are instructed to contact the Mentoring Coordinator to initiate the mentor selection process. The Mentoring Coordinator's role is to identify and evaluate the student's capabilities and interests and to suggest potential mentors currently involved in climate change research for the DOE. Potential mentors include scientists at either university, national laboratory, or small businesses conducting Small Business Innovative Research (SBIR) work on instrument development. The SURE student is then instructed to contact the DOE mentor directly to discuss possible research projects

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and also to arrange for housing at their research sites for the 9 week research portion of SURE. This approach differs from most undergraduate research programs which either pair the students with mentors by assignment or by allowing the mentor to select students from a batch of applicants. By guiding the GCEP SURE students through negotiations with a mentor directly the SURE fellow learns how to interact with senior researchers to define a research project and also to handle housing and other issues to set up their SURE experience. In this manner the GCEP SURE students are essentially learning how to find a graduate or thesis advisor in this process, an important skill in applying for graduate school and in succeeding in graduate education.

At the end of each summer period, all of the students and mentors are asked to evaluate each other. This allows for the student and mentor interactions to be assessed. This provides very useful feedback for the program and for the Mentoring Coordinator in future assignments for continuing SURE students as well as for assigning mentors in the program.

GRAF applicants are also required to identify a DOE mentor in addition to the student's university thesis advisor. The DOE mentor essentially acts to enhance the graduate student's climate change research thesis either by direct interaction and collaboration or by providing access to DOE facilities or capabilities such as the instrumentation and data sets available at the Atmospheric Radiation Measurement sites, Environmental Molecular Sciences Laboratory, the Center for Accelerator Mass Spectrometry (14C), or the various advanced light sources. The DOE mentor may also assist the student in access to and use of specific sites for study such as the Free-Air Carbon Exchange or Carbon Flux sites or high-end computers and the associated large and comprehensive regional and global scale models to address their thesis research questions.

The DOE mentors for GRAF projects are also required to not be at the same institution as the student, if possible. This insures that the student will expand his interactions outside of the immediate graduate institution and also encourages interactions between the university and current DOE research in climate change. As part of this effort to encourage the use of the DOE facilities, sites, and computational capabilities as well as enhanced collaboration with the DOE mentor, the Marvin L. Wesely GRAF fellow award was implemented in 2003. Dr. Wesely was a Senior Scientist at Argonne National Laboratory, who was an outstanding GCEP mentor and leader in the DOE Atmospheric Chemistry Program. He passed in January of 2003 from a rare form of heart cancer. In his memory, this award was established to honor the GRAF fellow who had made the best use of his/her DOE mentor during their thesis research. Thus, GRAF support focuses on directly connecting student research to the DOE climate change research efforts so that not

only are the students conducting climate change research towards graduate degrees, they are also contributing to the overall knowledge base needed to advance our fundamental understanding of key processes identified for DOE to improve climate change modeling and prediction, as well as to identify potential areas for mitigation. The success of this approach is quite apparent in the number of publications (279 citations and counting) that are directly tied to DOE climate change research interests as noted on the GCEP website (See:

<http://www.atmos.anl.gov/GCEP/Publications/index.html>

The current publications resulting from GCEP funding include 133 peer-reviewed papers, 18 papers in press, 67 oral presentations and 34 posters presented at national meetings, and 5 educational outreach presentations at universities and institutions.

### 3. ORIENTATIONS AND FINAL WORKSHOPS

A student orientation is held each year for both incoming SURE and GRAF fellows to provide for them an overview of the various areas of research conducted by the DOE Climate Change Research Programs. This included the Atmospheric Radiation Measurements and Atmospheric Science Program (Now the Atmospheric Systems Research program), the Program for Ecological Research and Terrestrial Carbon Program, and the Climate Change Prediction Program as well as other efforts supported by the DOE Climate Sciences Program in the Climate and Environmental Sciences Division of BER (See: <http://www.atmos.anl.gov/GCEP/>)

Overview presentations were performed so the students could visualize their research contributions to the current DOE Climate research programs.

Currently funded GRAF students are encouraged to present updates on their research in the appropriate sessions of the orientation. This allows for direct interactions between undergraduate and graduate students. Special lectures are also included in the orientation covering topics such as how to handle publishing papers, writing proposals, selecting graduate schools and advisors, putting together resumes, etc. This is included to develop the students awareness of what is required to be a successful graduate student and scientist, beyond the normal course work. These seminars were found by the students to be very enlightening and in many cases were their first exposure to these important aspects of developing into a successful research scientist.

Archives are given on the main GCEP home page for the various activities (orientation and final workshop presentations) as well as list of SURE and GRAF students and mentors ( See: <http://www.atmos.anl.gov/GCEP/> and archive link on top of page.

### 4. SURE TO GRAF BRIDGING

Another novel approach to increasing the number of U.S. undergraduates considering graduate school in the area of climate change research was the implementation of a bridging between the SURE and GREF programs. SURE students are highly encouraged to return to the program for subsequent years, as appropriate. Since SURE accepts students who have completed their freshman year with solid math and science backgrounds, this allows for continued summer research by many SURE students and has helped lead to publications for the undergraduates in peer-reviewed journals. Indeed, one SURE student was a lead author on paper in the Journal of Geophysical Research after completing only two summers in the program. We also allow for graduating seniors to work in SURE in the summer following graduation. This has been very useful particularly for those students entering graduate school with university mentors who are in the DOE climate change areas. In some cases this has allowed for students to get a head start on their graduate thesis research before entering graduate school.

Successful SURE students who do well and have good reviews from their mentors are also highly encouraged to consider "bridging" into GREF. These students are given a small number of points to their GREF application review scores and examined closely for possible GREF fellowships. Otherwise, they are asked to apply in the same manner as the other GREF applicants. A number of the SURE alumni have successfully applied for GREF support (See alumni page <http://www.atmos.anl.gov/GCEP/Alumni/AlumniDirectory.html> )

## 5. INSTITUTIONAL INTERACTIONS AND ARCHIVES

Another positive aspect of the GCEP program is the significant number of institutions that participate in the effort. A list of institutions as of 2003 is given at <http://www.atmos.anl.gov/GCEP/Information/Institutions.html> .

This list also gives an indication of the significant geographical distribution of the students involved in the program. Archives from the main GCEP home page list the past SURE and GREF students as well as mentors ( See: <http://www.atmos.anl.gov/GCEP/> and archive link on top of page). Note that the GCEP effort was quite diverse in the number of students from small and large schools, as well as having a significant number of minorities and women in both SURE and GREF. Thus the interactions at the orientations and final workshops also serve to let the students network with each other to find suitable graduate school programs and thesis mentors. In addition, GREF students help to guide SURE students and answer many questions about graduate school, thus encouraging many of them to consider that alternative.

The alumni page previously mentioned also shows that GCEP attempts to track its past SURE and particularly its GREF fellows. It is very important that the climate change education effort help these students find suitable positions in research, education, and industry at the state and federal levels. Thus, the mentors and particularly the mentoring coordinators need to be strongly committed to writing letters of reference for the students both immediately after and long after they have been in the program. These linkages between mentors and students and between students are very important, and leads to life-long interactions and potential collaborations with a truly interdisciplinary group. GCEP works hard to establish this type of interaction in its efforts and thus has developed a number of very successful GREF graduates as noted on the alumni page. See: <http://www.atmos.anl.gov/GCEP/Alumni/AlumniDirectory.html> ).

The alumni page lists past participants in GCEP and shows that the program has helped to produce qualified and successful members of the workforce. Many of these past students are continuing to work in Climate Change or related areas. One notable past GCEP student that has been successful in working for the American Meteorological Society is Dr. Paul Higgins, Senior Policy Fellow at AMS. We also have placed a number of students in faculty positions at major universities across the country who are now training future graduate students and who have had their students apply for GCEP support and are now thesis mentors for current GREF fellows. A number of GREF graduates have also found positions as postdoctoral researchers and staff scientists at the DOE national labs.

## 6. FINAL COMMENTS & LESSONS LEARNED

One major lesson learned over the years in GCEP is that a successful climate change education program needs to have good communication between the students and mentors. By having Mentoring Coordinators who are active members of the climate change research community, significant advantages for the overall program are insured. These include that expert lecturers are recruited for orientation that set a high level professional atmosphere for the students. The Mentoring Coordinators need to be dedicated to the program and willing to talk to students, answer email questions, and phone calls in a timely manner and continue to act as an advisor for the students during and after the program. This includes writing letters of recommendation for graduate schools, jobs, postdoctoral positions, advanced training, and other opportunities for the students. Having Mentoring Coordinators who are established as researchers in climate change is also an advantage for the fellows as reference letters have a stronger impact than those from non-climate change managers. This type of

commitment yields significant benefits for the students and helps to set an atmosphere of high level achievement that leads to undergraduates striving to enter graduate schools, graduate students striving to pursue careers in climate change, and ultimately senior scientists who in turn take the time to mentor new students (undergraduate and graduate students) to continue to enhance our capabilities in understanding the earth system so that we can develop environmentally sound energy strategies for the future.

It should be noted here that the DOE GCEP program will be completing its final selection of SURE and GREF students this year and will have the final group of GREF students graduating in 2013. The DOE has set up Office of Science Graduate Fellowships as well as Summer Undergraduate Laboratory Internships that continue to work toward workforce development. Information on those programs can be found at [http://www.er.doe.gov/Program\\_Offices/Workforce\\_Development.htm](http://www.er.doe.gov/Program_Offices/Workforce_Development.htm) .

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