RESEARCH EXPERIENCE FOR UNDERGRADUATES

SITE PROGRAM IN SOLAR AND SPACE PHYSICS

THE LABORATORY FOR ATMOSPHERIC AND SPACE PHYSICS
THE UNIVERSITY OF COLORADO
THE NCAR HIGH ALTITUDE OBSERVATORY
THE NOAA SPACE WEATHER PREDICTION CENTER
THE NWRA COLORADO RESEARCH ASSOCIATES

2008 REU students.

Front left to right: Chris Lech, Sabrina Hurlock, Jimmy Grayson, Ajeeta Khatiwada, Elin Deeb, Julie Feldt, Jim McGrail, Brian Kirby, Ian Cohen, Matt Igel, Raktim Sarma, David Graham, Jeff Tessein

2008 Annual Project Report

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Project Summary – 2008 Boulder REU Site Program

The University of Colorado's Laboratory for Atmospheric and Space Physics (CU/LASP), leading a consortium of Boulder-based solar and space physics programs, continued a Research Experience for Undergraduates (REU) Program in Solar and Space Physics for its second year. Funded primarily by the National Science Foundation (NSF) with consortium members supporting additional students, the goal of the program is to encourage U.S. undergraduate students to pursue graduate school studies and professional careers in solar physics and its related research and engineering disciplines. LASP's REU program began with a weeklong summer school spanning topics in solar and space physics with lectures given by scientists from across Boulder. After the summer school, students work closely with research scientists to complete an 8-week research project at one of the following organizations: CU/LASP, the National Center for Atmospheric Research (NCAR) High Altitude Observatory (HAO), the NOAA Space Weather Prediction Center (SWPC), the Northwest Research Associates (NWRA) Colorado Research Associates (CoRA), and the South West Research Institute (SwRI). At the close of the program, students present their research both as a presentation and poster, which is evaluated by mentor scientists as well as other scientists, graduate students and professional researchers from the participating organizations.

The 2008 REU program had fifteen participants, five of which were paired with mentors at LASP, three at NOAA/SWPC, three at NWRA/CoRA, three at NCAR/HAO, and one at SwRI. One REU student from the 2007 program returned to conduct research with his team from the previous year, providing a model for the new students to aspire to. Projects ranged from theoretical predictions, to applied science using observation or previously collected data, all of which included mathematical modeling procedures. In addition, two students actively engineered instrumentation for use in space physics applications and testing. The topics for this year were considerably more varied than those from 2007 due, in large part, to the span of mentors selected from the participating institutions.

The program was modified based upon student's feedback from the previous year. The weeklong summer school had more varied topics, less homework, and more peer interaction than in 2007. In addition, the contest to send the best student research to a scientific conference that accompanied the presentations and poster session was eliminated as students felt the competition undermined their accomplishments.

The success of the 2008 REU program in Solar and Space Physics can be attributed largely to the dedicated mentors at the participating organizations as well as the communication between students, mentors, and organizations. Graduate and post-doctoral students assisted with instruction both during the summer school program and provided continual support for the duration of the program.

Participants

Recruitment

The 15 undergraduate students (10 male and 5 female; 11 Caucasian, 3 Asian, 1 African American) were selected from a total of 60 applicants. Three students selected were foreign students paid for by non-NSF funding by the participating organizations. Students were recruited for the 2008 program through the SPA newsletter, SolarNews, through distributions of flyers to a broad spectrum of colleges and universities, through all consortium institutions and their listservs, and through the LASP REU Website (http://lasp.colorado.edu/reu). Particular efforts were made to recruit students from underrepresented areas, using NASA's Minority University Space Initiative (MU-SPIN) network and contacting astronomy, physics, engineering, mathematics, and natural sciences departments at Historically Black Colleges and Universities, as well as Hispanic Serving Institutions.

Selection and Project Pairing

Scientists interested in mentoring an REU student were asked, in the Spring of 2008, to submit a project proposal which outlined the project and the mentors, along with the skills the student would need to successfully complete the project. More than one mentor was generally required for the project, and all mentors were required to participate in the summer school and weekly brown bags, as well as the student symposium. Projects were reviewed for scientific merit and quality of student involvement.

A review panel made up of scientists from each REU institution met to discuss candidates and the project proposals. Students were chosen for the REU program based on background, grades, letters of recommendation, and articulation of areas of interest. Students were paired with research projects based on their background and ability, as well as their stated interest. Students were notified of their acceptance, along with their project assignment. They were given a chance to change their project. Mentors and students were then put into contact with each other in the month or two before the beginning of the program, in order to get the student ready for the summer.

Table 1. List of Participants/College/Advisors/REU Site

Student	College/ University	Advisor(s)	REU site
Ian Cohen	Boston University	Fran Bagenal, Peter Delamere	CU/LASP
Jennifer “Elin” Deeb	CU Boulder	Dusan Odstrcil	NOAA/SWPC
Julie Feldt	University of Kansas	Marty Snow, Greg Holsclaw	CU/LASP
David Graham	Glasgow	Scott McIntosh	NCAR/HAO
James Grayson	University of California, Berkeley	Scott McIntosh	NCAR/HAO
Sabrina Hurlock	East Tennessee State University	Curt de Konig, Michael Gehmeyer	NOAA/SWPC
Matthew Igel	North Carolina State University	Jennifer Gannon	NOAA/SWPC
Ajeeta Khatiwada	Linfield College	Ashley Crouch, K.D. Leka	NWRA/CoRA
Brian Kirby	University of Michigan	Erik Richard, Jerry Harder	CU/LASP
Jacinda Knoll	Oxford University	K.D. Leka, Graham Barnes	NWRA/CoRA
Christopher Lech	Embry-Riddle Aeronautical University	Craig DeForest	SwRI
James McGrail	University of Michigan	Marty Snow, Erik Richard	CU/LASP
Chris Moore	University of Iowa	Phil Chamberlin, Tom Woods	CU/LASP
Raktim Sarma	University of Texas at Dallas	Qian Wu, Alice Lecinski	NCAR/HAO

2008 Program Activities

Solar and Space Physics Summer School

The first week of the REU program was devoted to a summer school that gave students a complete overview of solar physics, space weather, the Sun-Earth connection, and instrument design. In addition, a half-day course in IDL was provided for those students that needed this background for their project.

The goals were to provide necessary background for the research the students would undertake and give a broad overview of the science and engineering involved so that students could better understand the research of their peers even if it did not directly apply to their own research. The talks and sessions were given by scientists and engineers from the all of the participating organizations.

Solar and Space Physics Summer School 2008 June 9-13	
Speaker	**Topic**
Eparvier, F (LASP)	**Sun-Earth System Overview**
Woods, T (LASP)	**Current and Future Solar Observing Missions**
Richard, E (LASP)	**Spectroscopy and Instrument Design**
Lindsey, C (NWRA)	**The Solar Interior and Introduction to Helioseismology**
Harder, J (LASP)	**Solar Irradiance/Radiometry**
Chamberlin, P (LASP)	**Solar Flares**
DeForest, C (SWRI)	**Coronal Mass Ejections**
Gosling, J (LASP)	**The Solar Wind**
Gannon, J (SWPC)	**The Earth's Magnetosphere and Radiation Belts**
Bagenal, F (LASP)	**Planetary Magnetospheres**
Viereck, R and B. Murtagh (SWPC)	**Space Weather and the Space Weather Prediction Center**

Solar and Space Physics Summer School 2008 – Afternoon Activities June 9-13	
Day	**Topic**
Monday	**Spaceflight instruments and their optical design**
Tuesday	**Finding current satellite data (Web Based)**
Wednesday	**CISM Solar Wind Activity**
Thursday	**IDL Summer School (See below)**
Friday	**Space Weather Block Diagram (Picture on title page)**

IDL Summer School 2008: Dr. Marty Snow and Rachel Hock
Topic What is IDL? Basic Syntax (data types, vectors, arrays, etc.) Functions, Procedures, & User Library Basic I/O (including exercize) Plotting & Printing (including another exercise) Image Processing Tips & Tricks

Research Projects

The summer 2008 LASP REU students spent an average of 8 weeks working as full-time research assistants, with some continuing their research into the fall semester or employed by the organization with which they worked. At the end of the program, each student presented his or her research work to mentors and REU peers, and the session was open to scientists from the community as well. This gave students the unique opportunity to present research in a professional setting, getting feedback, encouragement, and research assistance from participants. The students also presented research work during a poster session. A brief description of each student's project follows.

Ian Cohen (Boston University) [Advisors: Fran Bagenal, Peter Delamere, CU/LASP] analyzed Jovian auroras and found a connection between open field lines and the main jovian auroral oval. Using established models for the Jovian magnetic field and magnetopause, he searched for field lines that cross the magnetopause and thusly might be candidates for magnetic reconnection that could open the magnetosphere to the interplanetary magnetic field. Although a field line crossing the magnetopause does not necessarily mean reconnection will occur, Ian discovered a plausible relationship between open field lines and the main auroral oval (including structure on the dawn facing side). This establishes a potential link between the main Jovian aurora and solar activity.

Jennifer "Elin" Deeb(CU Boulder) [Advisor: Dusan Odstrcil, NOAA/SWPC] modeled arrival times of Coronal Mass Ejections (CMEs) using various parameters in the SWPC-developed modeling system which uses fitted coronagraph observations, specifies 3D ejecta, and drives the 3D numerical magnetohydrodynamic code ENLIL. She compared CME events to the model and used best-fit procedures to determine the most accurate arrival time prediction parameters.

Julie Feldt (University of Kansas) [Advisors: Marty Snow, Greg Holsclaw, CU/LASP] used the SOLar-Stellar Irradiance Comparison Experiment (SOLSTICE) on the Solar Radiation and Climate Experiment (SORCE), far-ultraviolet data of the atmosphere, Moon, and Sun to find the reflectance of the moon at the Lyman-a line (121.6nm). The SOLSTICE observations were used to calculate the disk integrated albedo of the Moon, a value found to be ~ 2%.

David Graham (Glasgow) and **James Grayson** (University of California, Berkeley) [Advisor: Scott McIntosh, NCAR/HAO] used multi-wavelength transition region spectral images taken by the SUMER instrument on the Solar and Heliospheric Observatory (SOHO) to investigate the spatial dependence of double and single Gaussian spectral profiles in the chromospheric network. Broad double Gaussian spectra are thought to be a signature of dynamic motions in the solar atmosphere. After fitting these profiles using genetic algorithms, they found that previous work at a single wavelength has been misleading in its representation of double component spectra as being essentially confined to bright network regions. They discovered that through closer inspection of the genetic algorithm fitting process, and by using images at multiple wavelengths, this apparent spatial relationship would still need to be verified. They discovered that information on line widths and Doppler shifts would improve and support a two spicule model by tracking where the double fits appear at different wavelengths and at different network locations which could not be done with the data they were given.

Sabrina Hurlock (East Tennessee State University) [Advisors: Curt de Konig, Michael Gehmeyer, NOAA/SWPC] developed a prototype IDL program, based on the Elliptical Cone Model proposed by Hebe Cremades in 2005, to help predict the 3D velocity and direction of a coronal mass ejection. Using the parametric equations that describe the elliptical cone, one can find the lengths of the semi major and semi minor axes, the orientation or tilt of the ellipse, and the length of the radial axis of the cone. When used on a sequence of images, this model will predict, upon completion, the 3D velocity of the coronal mass ejection. She described preliminary results showing the possible cone models that can be fit to the SOHO (Solar and Heliospheric Observatory)/LASCO (Large Angle and Spectrometric Coronagraph) CME observation of December 13, 2006.

Matthew Igel (North Carolina State University) [Advisor: Jennifer Gannon, NOAA/SWPC] studied models of Earth's magnetic field that are crucial to research of near space phenomenon. He analyzed off-equatorial shape and accuracy of the magnetic field of several models included in the ONERA-DESP library. He binned the analysis by the Geomagnetic Equatorial Index (DST) based substorm periods, geomagnetic activity index (Kp), and by geomagnetic latitude. His results confirm well-known equatorial performance problems and illuminate new areas of stretching and compression of field lines within models. He compared Cluster and Polar satellite magnetometer measurements to model outputs of scalar magnetic fields, which show poor performance during peak storm times and early recovery, during high Kp periods ($Kp \geq 4$), and at high latitudes (>60°). Additionally, 3 dimensional magnetic field line plots confirm decreasing model performance with increasing geomagnetic activity.

Ajeeta Khatiwada (Linfield College) [Advisors: Ashley Crouch, K.D. Leka, NWRA/CoRA] studied the initiation mechanism for solar energetic events by examining the Helical Kink Instability of a twisted flux tube as a potential mechanism. Measuring the amount of magnetic helicity or calculating the number of times magnetic field lines wind around the axis of a flux tube may enable one to predict the Kink Instability. She modified a pre-existing Genetic Algorithm optimization code and established the best parameters to fit the model to observational data from NOAA AR 7201 observed on 06/19/1992 with the NSO/HAO Advanced Stokes Polarimeter. She established that the flux tube observed is susceptible to Kink instability and the center of the torus (the circular structure of the flux tube as proposed by one of the models) emerges from solar interior. She found that more appropriate models may be required to determine the twist parameter of the flux tube.

Brian Kirby (University of Michigan) [Advisors: Erik Richard, Jerry Harder, CU/LASP] developed an experiment to determine the temperature coefficient of radiant sensitivity for the photodiodes used on the Spectral Irradiance Monitor (SIM) instrument. The solar irradiance is broken into its individual wavelengths and is measured with high accuracy by the SIM. In order to meet the required accuracy of 0.01%, all sources of error in SIM must be understood and corrected. Brian's experiment addressed one of the sources of error, the change in radiant sensitivity, or the ratio of current generated by a photodiode per watt of energy received due to temperature fluctuations experienced by the photodiodes.

Jacinda Knoll (Oxford University) [Advisors: K.D. Leka, Graham Barnes, NWRA/CoRA] studied solar flare prediction by analyzing a large SOHO MDI dataset of line-of-sight magnetograms (prepared by J. McAteer) using the statistical technique of discriminant analysis. She investigated dataset limitations and various corrective methods, as well as how the predictive power for solar flares varies with parameters chosen, year of data collection, and distance of the data from disk center. She found that use of line of sight magnetograms is limited because various corrective methods must be employed to compensate for lack of full vector information. She primarily used two corrective models, a simple observing-angle correction and a potential field correction. Flare distance from disk center has a profound effect on the predictive power of these models, with accuracy of the prediction falling nearly 200% between including data only within 5 degrees of disk center and including data through 45 degrees. She found that further research is needed to analyze these findings in more detail.

Christopher Lech (Embry-Riddle Aeronautical University) [Advisor: Craig DeForest, SwRI] searched for high frequency waves in the solar atmosphere using image sequences taken by IBIS, a scanning narrow band pass imager. He converted these data into Dopplergrams and Fourier transformed them to obtain an energy spectrum. High frequency waves were expected to show up as bright ridges in the k-ω diagram. While he found some structure in the 100mHz range, no discernible ridges were present.

James McGrail (University of Michigan) [Advisors: Marty Snow, Erik Richard, CU/LASP] studied the Magnesium II index, which has been shown to be a good measure of solar activity because it is highly correlated to EUV and FUV variability. It is measured as a core-to-wing ratio around the emission feature at 280 nm. James analyzed data in this region of the spectrum of many different instruments from 1978 to the present. By comparing these different sets of data with several techniques, he created a new composite Mg II index that is better at predicting solar irradiance than the standard NOAA Mg II index.

Chris Moore (University of Iowa) [Advisors: Phil Chamberlin, Tom Woods, CU/LASP] worked on the spectral decomposition of the total solar irradiance (TSI) radiative energy release during a flare. He was able to find the spectral contributions during the impulsive and gradual phases for the spectral ranges including the Vacuum Ultraviolet (VUV; 0.1-200 nm) spectral range using the Flare Irradiance Spectral Model (FISM) as well as the Hard X-Ray energies using the Raven Rumany High Energy Solar Spectral Imager (RHESSI). Chris also made initial attempts to also find the energies in the visible and Radio emissions, but was limited by data limitations, their noise, and their observation cadence. ***Chris has been invited to present his results at the upcoming conference in Napa, California titled 'The Onset of Solar Cycle 24' in December 2008.***

Raktim Sarma (University of Texas at Dallas) [Advisors: Qian Wu, Alice Lecinski, NCAR/HAO] built an improved and more sophisticated version of the All Sky Camera. This camera will replace the older one at Resolute Bay and is an effort in the direction of setting up the Advanced Modular Incoherent Scatter Radar (AMISR) at Resolute Bay, Canada. AMISR is a radar facility that is used by scientists all over the world to study upper atmospheric activity. He created the software to operate The All Sky Camera's pointing control, filter wheel orientation, and exposure time, which can be controlled by remote users. The All Sky Camera consists of a Fish Eyed Lens, Filter Wheel, Focus Mechanism and a CCD Camera. Raktim integrated them into a Graphical User Interface and the instrument is controlled by software he wrote in C++.

Standard operation of the instrument is autonomous and follows pre-written scripts to perform required tasks.

Brown Bags and Science Presentations

Brown bag sessions were provided weekly to give students an opportunity to experience the environment and research activities at the various organizations. Each week, the session was held at one of the facilities, science researchers gave short presentations, and the facilities were toured. Toward the end of the summer, students began presenting their research in 10-15 minute presentations, receiving feedback from their peers and scientists to aide with research progress and to get ready for their final presentations.

On July 31st, students presented their work at a Student Symposium held at CU/LASP. Students prepared scientific posters, as well as a 30-minute presentation. The Symposium was attended by all of the REU mentors, along with interested scientists from all of the REU institutions. Presentations and posters can be found at:

http://lasp.colorado.edu/~reu/summer-2008/final-schedule.html

Evaluation of the 2008 REU Program

A series of formative and summative evaluation tools were used to determine the progress and effectiveness of the REU program on participants. Our evaluation employed a mid-summer and post-summer anonymous survey to gauge the impact of the program, both in terms of participant growth and to determine areas where the program might be improved. In addition, participants were polled for ideas for program improvements, new lines of inquiry, and suggestions for activities are a vital component of the program development.

Throughout the summer, students met with REU program staff to see how things are going, identify any trouble spots, and make sure that the program is meeting the participants' needs. This provided critical feedback for the staff and allowed the program to be optimized for each student. Likewise, throughout the program, science teams were asked to assess the progress of the undergraduate, in hopes of identifying problems that might be addressed "mid-flow".

Students will continue to be accessed annually by program staff to identify career choices and destinations (and have signed permissions to allow us to follow them). Follow-up will include career surveys developed by LASP to track its graduate students after they've completed their degree. We will modify this survey for the REU program. It is our hope to be able to track students for at least 5 years. Depending on their career track, this will allow us to gauge their pursuit of advanced degrees and/entry into a profession. This year's evaluation results can be found in Appendix A.

Lessons Learned for the 2009 REU Program

Although the student feedback was largely positive, we are taking many of their comments to heart and looking at the following changes to the program:

- As in 2007, the REU students still rated the summer school as a mixed bag. Some found that it was too basic and didn't relate to their particular project well. This reflects, to some degree, the high quality of students this summer. Many of the attendees had substantial backgrounds in solar and space physics before arriving in Boulder. In an effort to address this issue in 2009, we will be sending out a survey to students before their arrival to assess their background and knowledge base, using that information to design the summer school curriculum.

- Students this year, unlike 2007, did not find the brown bags a useful way to interact with each other or with staff. We are looking developing the brown bags more fully for 2009, assigning specific topics and areas to presenters.
- This year, unlike 2007, most of the projects that the REU mentors designed were larger than could be done within the REU program timeframe. While this has lead to most of the 2008 students continuing to work with REU mentors and expand their experience, we are going to work more closely with next summers mentors to designing their projects to fit within the time allowed.

Current Status for 2009

We currently anticipate 100 applications for the 2009 REU Program in Solar and Space Physics. We have the same resource commitments from the participating institutions and believe we will be able to fund between 12 and 14 students. In addition, two students from 2009 will be returning to Boulder to continue working with their mentors.

APPENDIX I – Boulder REU Program Evaluation

Part A. Post-REU Questionnaire

2008 REU Evaluation		1= Agree	5= Disagree AVG.
A. Application Process			
1	Applying to the REU program was straightforward.		1.1
2	The REU staff was responsive in providing information.		1.2
3	I felt that the project I was assigned to met my interests		1.9
4	The initial program package contained the information I needed to get ready for the program.		1.7
B. Bear Creek Apartments			
1	The apartment met my needs for the program.		1.2
2	The household items provided by the program were sufficient for the summer.		2.6
3	The Bear Creek staff was responsive.		1.7
4	The Bear Creek Apts. are well situated, allowing easy access to REU sites.		1.4
C. Travel arrangements			
1	Travel arrangements were straightforward.		1.3
2	REU staff was supportive and helpful in arranging travel.		1.1
D. The REU Summer School			
1	The week-long summer school was a good preparation in solar and space physics.		2.0
2	The lectures were informative and useful.		2.0
3	I knew most of what was presented in the summer school.		1.8
4	The summer school provided information I needed for my project.		3.3
5	The summer school was a good use of my time.		2.6
6	The IDL short course was useful.		1.7
7	The IDL short course helped me with my project.		1.8
8	The IDL provided me with enough information to help me.		2.2
E. The REU Project			
1	My REU project was well matched to my stated interests.		1.9
2	My advisors spent time with me getting started.		1.7
3	My project was well defined with a clear path of tasks and analysis.		1.7

4	**My project was completed during the summer.**	**1.8**
5	**My project was a reasonable challenge for me.**	**1.5**
6	**My project was too easy.**	**4.4**
7	**My project was too hard.**	**4.5**
8	**When my advisor wasn't available, others in their groups were.**	**1.5**
9	**I felt that my mentor created a supportive working environment that allowed me to work effectively.**	**1.2**
10	**If I had a chance, I would consider working with my advising team again.**	**1.4**
11	**The brown bag lunches were a good way to keep in touch with the group.**	**2.8**
12	**I expect to continue to work on my project with my mentor after the summer is over.**	**2.2**

F. Extracurriculars

1	**The REU staff provided good opportunities to explore Boulder and Colorado.**	**2.2**
2	**The REU staff was responsive to needs as they arose.**	**1.7**
3	**I wish there had been more activities planned.**	**2.7**
4	**I didn't really need any activities planned.**	**3.5**

F. Overall

1	**I would recommend the REU program to others.**	**1.5**

Part B. REU Student Comments about their Mentors

Student #1
- [My project] turned out to be challenging and on the cutting edge of what we know.

Student #2
- …a great opportunity and learning experience.

Student #3
- I felt it was difficult to find you and get help…A second advisor would have been very helpful.
- Overall, I do feel the program was a valuable experience.

Student #4
- …a truly awesome research experience.
- I can't thank you enough for all the time you spent with me.

Student #5
- I liked how autonomous I was.
- I thought you guys were really good mentors.

Student #6
- I think the level of work and the amount of work was perfect for the summer.

Student #7
- My summer project was very good and I'm really happy that I finished in time.

Student #8
- You were a great motivator and inspiration.
- You were always there when I had questions.

Student #9
- I had a fantastic time working with you this summer!
- I appreciate your patient and kindness.

Student #10
- The thing I enjoyed the most…is that you were available most of the time when I needed you.
- I felt that you were trying to teach me a lot of things in small steps.
- You always showed interest in my presentations and posters.

Student #11
- You were also very involved with the REU activities…attending most of the brown bags and interacting not only with me but with many other students.

Student #12
- I felt comfortable asking you questions and coming to you for help.