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The 'Ideal' Climate Change Ph.D. Program

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DISCCRS

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Working Group Report
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1.0 Introduction

The threat of climate change is one of the most pressing issues facing humanity in the coming century. In order to increase resiliency and prepare for vulnerabilities associated with climate change, society will look to science to provide answers. However, the science of climate change is complex and multi-disciplinary; many aspects of climate-change research, particularly dealing with adaptation and impacts, require a much broader perspective and greater scientific knowledge than a Ph.D. candidate typically gains in a traditional discipline. How then can graduate programs meet both the disciplinary demands of traditional programs and the interdisciplinary needs of climate-change research in order to best train the next generation of scientists? While there are no simple answers, a symposium brought together 40 recent Ph.D. recipients from 36 institutions and 11 countries (Table I), in part to help address this question by discussing an 'ideal' climate-change Ph.D. program. Sponsored by the American Meteorological Society, American Geophysical Union, American Society of Limnology and Oceanography and Ecological Society of America, the Dissertations Initiative for the Advancement of Climate Change Research (DISCCRS) seeks to bridge the gap between student and new professional. (see http://aslo.org/phd.html for program details and information about future symposia) The DISCCRS Symposium, held March 10-15, 2003 in Guanica, Puerto Rico, was the first in what is hoped will become a series. The DISCCRS symposium participants were competitively selected for excellence and diversity of research, with all participants having completed their Ph.D.s after January 1, 2000. The main goal of the symposium was to foster interdisciplinary connections and early professional development. However, the forum also provided a unique opportunity to ask these new professionals to reflect on their recent graduate experience and offer some practical advice on how institutions could best meet the needs of the next generation of climate-change researchers.

The 40 participants were organized into 5 Working groups and charged with designing the 'Ideal PhD Program for Climate-Change Studies'. Over a three-day period each group was asked to highlight the best features of their particular graduate programs and use their experience and collective imagination to brainstorm about the 'ideal' program. After small-group discussion, participants re-convened to report and discuss their results. Finally, at least one representative from each of the groups was self-selected to summarize the group discussions and write a final report. This report outlines the DISCCRS participants' views on how to develop an 'ideal' climate-change program, one which produces well-trained, highly qualified Ph.D.'s that are solidly grounded in their traditional disciplines, yet also are capable of interacting and collaborating with scientists from different disciplines. The components of an 'ideal' climate-change program are discussed in this report, including a suggested approach to course design and the roles of faculty in professional development. This is followed by a representative list of interdisciplinary programs that that attempt to provide a more holistic approach to climate-change science. The comments in this report are expressly related to the contributing authors (hereafter the Working Group), and they may not reflect views held by other recent graduates or the institutions the DISCCRS participants work for. However, as recent recipients of Ph.D.s in a wide variety of disciplines and countries, the Working Group believes that this document offers a rare opportunity to express the views of the upcoming generation of scientists with an interest in climate change.

Table I. Institutions granting PhD degrees to the 40 participants of the 2003 DISCCRS symposium. Thirty-six institutions and eleven countries are represented. Unless otherwise stated, the universities listed are in the United States.

Australian National University (Australia)
Boston University
Brazilian Institute of Space Research (Brazil)
Center for Scientific Research and Higher Education in Ensenada (Mexico)
College of William and Mary
Columbia University
George Mason University
Indiana University at Bloomington
Kansas State University
Massachusetts Institute of Technology
McMaster University (Canada)
New Mexico Institute of Mining and Technology
Princeton University
Rutgers University
State University of New York at Albany
Swedish University of Agricultural Sciences (Sweden)
Université Pierre et Marie Curie (France)
University of Alaska at Fairbanks
University of Arizona
University of California at Berkeley
University of California at Davis
University of California at Los Angeles
University of California at Santa Barbara
University of Cambridge (United Kingdom)
University of Colorado at Boulder
University of East Anglia (United Kingdom)
University of Hamburg (Germany)
University of Minnesota-Twin Cities
University of Nebraska
University of South Carolina at Columbia
University of Texas at Austin
University of Vienna (Austria)
University of Washington
Uppsala University (Sweden)
Washington State University
Weizmann Institute of Science (Israel)

2.0 Elements of the 'Ideal' Ph.D. program

The interdisciplinary nature of climate-change research necessitates that a group of researchers, with varied backgrounds and interests, work together to address related research questions. Although climate change is an interdisciplinary field, the Working Group believes that students should retain a specialization in a discipline housed within a traditional department, since a 'jack-of-all-trades is a master of none', and the advancement of science often requires specialized knowledge. However, it is equally important for young professionals to be exposed to collaboration and cross-fertilization as students, or they will experience difficulty in interacting with researchers from other disciplines once they graduate. To meet the conflicting

demands of depth and breadth, the Working Group recommends that students be exposed to collaboration and cross-fertilization under the auspices of an interdisciplinary Climate Change Center/Program (CCC/P). The Working Group strongly believes that students trained in fundamentals, yet adequately exposed to collaboration with other disciplines through their affiliation with a CCC/P, will yield the best results for students, universities, and climate change science as a whole. Unfortunately, this places the graduate student in the tenuous position of having to maintain depth in their core discipline while maintaining breadth of exposure and learning in cognate disciplines. Therefore, coursework and related experiences for the graduate student in climate change science must facilitate this balance between specialization in a core discipline and opportunities for exposure to wider, related fields of study. Additionally, while the graduate student's research topic needs to remain firmly grounded in their core discipline, the significance and impact of their research should be disseminated to the wider climate change research community.

It is not sufficient to merely assemble an interdisciplinary group of researchers under the umbrella of a CCC/P, there also must be strong interaction amongst the members. Faculty, departmental, and institutional support for interdisciplinary research and interaction must be robust in order to successfully educate future climate-change scientists. By creating a CCC/P, universities can pool the resources of many departments without the need to create a new department (which could negatively affect traditional disciplines). Such a center or program would create a critical mass of people, knowledge and resources. With an interdisciplinary center, large universities can concentrate researchers from different backgrounds in one location (either physically or virtually), which often fosters the kind of interdisciplinary research needed in climate-change science. In smaller colleges, the concept of an interdisciplinary program could effectively train graduate students by drawing together resources from smaller departments, even though a critical mass does not exist in any one department.

Regardless of program size, faculty must be effective mentors in order to create an 'ideal' climate-change Ph.D. program. This entails treating the student with respect as a collaborator and assisting the student with job placement following completion of the degree. Additionally, students should have significant interaction with professors from different disciplinary backgrounds, thereby fostering an interdisciplinary mindset to research. Finally, universities must support faculty that are involved in the interdisciplinary program or center, by recognizing the value that these programs offer, and appropriating the necessary funds and providing release time to develop and support interdisciplinary faculty and programs.

2.1 Program Structure

The 'ideal' climate-change Ph.D. envisioned by the Working Group involves the development of a non-degree granting CCC/P that incorporates faculty from the social, life, and physical sciences. The Working Group is concerned that the time and effort needed to create a degree-granting program would require a commitment of resources that in the current economic environment is unlikely to be tenable. The Working Group believes that students exposed to other disciplines through the CCC/P will develop the needed skills to be future leaders in the climate change community, regardless of their degree. Nonetheless, the Working Group would encourage universities to grant some form of recognition of the student's involvement in the

CCC/P, such as a climate-change Ph.D. minor (see section 3 for a description of a such a degree as granted by the Institute of the Study of the Planet Earth (ISPE) program at the University of Arizona).

Coursework: The curriculum for an 'ideal' Ph.D. climate-change program consists of 1) a limited number of core courses in theory and research methods that are vital to climate-change science, and 2) traditional disciplinary courses that provide students with depth of knowledge in their chosen discipline. The coursework associated with the CCC/P should introduce students to the multitudes of perspectives and sub-fields housed under climate change science. Hopefully, these classes will serve to increase student awareness of the interrelationships between the earth's surface and atmospheric processes, ecological systems, and human activities. The Working Group advocates a lecture-based class focusing on the History of Climate Change and a seminar series that covers 'hot' topics in climate change as essential components of a CCC/P. Further course details are provided in Box 1.

Semester away/short courses: The semester away/short courses would expose students to alternative approaches and methodologies used to tackle particular research questions. Some time away from the home institution is highly encouraged for those who have spent their entire post-graduate career at the same institute or have undertaken graduate study at a small university with limited resources. It is likely that the CCC/P could more easily facilitate (compared with a traditional disciplinary department) these interactions with other departments and institutes that focus primarily on climate-change research. It would be beneficial to set up a semester away/exchange program (similar to undergraduate programs) at a sister university where students can interact with a wider group of climate science researchers. Short courses such as those offered at University College London (http://www.geog.ucl.ac.uk/ecrc/teaching.stm/) can also provide students with a similar experience, increase their skill set, and perhaps most importantly, help students develop contacts across the wider climate-change research community.

Seminars: Informal interactions with faculty, visiting researchers, and other students are probably one of the easiest ways for students to learn more about the research being carried out in their field. The CCC/P could facilitate these interactions and provide a forum for these informal interactions. A (in)formal seminar series, in which graduate students and researchers from varied backgrounds conducting climate-change research present on all manner of topics in a central location, would do much to increase the exposure of students currently cloistered in their respective departments to the wider climate-change community. A well-attended weekly seminar series such as this can serve to introduce students to the broad range of research topics that are of interest to their colleagues and may inspire their own research, thereby creating a more fertile research environment.

Role of professional societies: Every student should maintain membership with at least one professional society. Generally, responsibility for ensuring this falls upon the student's mentor or more broadly the department in which the student is enrolled. However, the CCC/P may be able to introduce the student to professional societies outside of their advisor's area of expertise.

Box 1: Specific Courses/Lectures/Seminars

History of climate-change science: This class would develop the major themes, issues and concepts that have been addressed or have arisen from global/climate change research. It should encompass the key developments in the fields of geology, biology, hydrology, geochemistry and atmospheric science that have furthered our understanding of past and present climate change. Particular issues that can be used to demonstrate the value of multi-disciplinary approaches to climate-change research include the carbon cycle and atmospheric carbon dioxide, global warming, conservation and biodiversity, sea level rise, depleted ozone and other aspects of atmospheric chemistry, etc. The issues addressed in this class could also be used to introduce students to the policy/political aspects of global/climate change research. For example, a class could consider how climate-change research was used in developing the IPCC: Climate Change 2001 report.

Hot topics in climate-change research: Incoming students could present recent, cutting-edge research in their particular area of expertise or the area in which they plan to focus. This class would probably take the form of a seminar series that would largely be guided by student interest and input. This class may also serve as the venue for faculty affiliated with the program to present their own research. The goal of this class is to expose students to the cutting edge of the various sub-fields of climate-change research and to introduce them to novel techniques and methods that are being used to advance our understanding of the climate system.

Perspective on Global Climate Change: Climate, Environment and Society: This class would introduce students to the complex inter-relationship(s) that exists between the natural environment, the social environment, and climate change. Subject matter that could be addressed includes the human costs of global/climate change, obstacles to reducing greenhouse gas emissions, impact of deforestation on climate, climate change and development issues, etc.

Climate Change: Science and Policy Implications: Policy makers increasingly are using science to support their views on regulations and legislation. As we train the next generation of scientific leaders, we must educate them early in their careers on how science is used in policy environments. Historically, few programs have acknowledged, let alone given instruction, in science and policy. While science must remain politically neutral, scientists must understand the policy implications of their work.

Professional societies provide a wealth of information, including current news, legislative policy development, science findings, job opportunities and upcoming conferences. By attending regional and international conferences, the student is exposed to leading scientists, unpublished data, and cutting-edge ideas in climate-change research. It is at these meetings where the graduate student will begin to establish themselves in their discipline, and to form the network of associations with other scientists that is essential to the student's professional development.

The Bulletin Board/Webpage: The presence of a bulletin board (both physical and virtual) serves as a clearinghouse for opportunities in climate-change research, fellowships, grants, short courses, and fieldwork opportunities. This board could also be used to post papers and articles pertaining to recent climate-change research.

Conferences/Outreach: It is important for students to communicate their work early and often at professional conferences and workshops. Dissemination of their research in these forums can provide students with valuable feedback from other scientists and further increase their exposure to the wider climate-change community. Moreover, the Working Group believes that scientists have a duty to present their research to peers and to the public. Some meetings with excellent multi-disciplinary attendees are: the American Geophysical Union fall and spring meetings, the Geological Society of America annual meeting, and the AAAS meetings. Additionally, students should take the opportunity to present their research to a wider "non-academic" audience. Unfortunately, these types of presentations typically are not encouraged by advisors during a student's graduate career. Many informal opportunities exist locally, and others could be easily created. For example, local libraries and museums often have a science lecture series for the public where university professors and graduate students discuss topics of public interest. Judging local science fairs is another form of outreach; often local schools are scrambling to find judges and welcome graduate students. The "Partner in Science" series, where students visit local elementary schools, is another outstanding outreach opportunity. Caution must be exercised because it is easy to get overextended in a graduate project, but it is increasingly important to present scientific results to the general public in order to best inform decision makers of relevant climate-change research. Other areas where a student might disseminate knowledge are through teaching at local community colleges, co-op classes, and short courses.

2.2 Faculty

Even with an outstanding program structure, poor coordination of faculty, faculty that are more interested in protecting turf than collaborating across disciplines, or faculty lacking energy and vision could ruin the CCC//P and a student's academic training. All things being equal, the 'ideal' Ph.D. program would benefit from large and academically diverse faculty, faculty adept at mentoring students, and strong institutional support for the faculty participating in an interdisciplinary climate-change program.

Faculty size: It takes a critical mass of interested faculty members to establish a program of graduate study in climate change. Since the CCC/P envisioned here can draw faculty from several different disciplines and departments, it could successfully exist even in smaller colleges. However, the magnitude of resources available from different departments at the larger schools may create a more sustainable program. A large CCC/P can create an excellent environment for interactions among teams of researchers.

Faculty mentoring: Regardless of the graduate program's physical size, location, or structure, the student's development is highly dependent upon their major professor. A good major professor is first and foremost a good mentor, who will train and direct the student through the difficult transition from student to peer. The Working Group feels an in-depth discussion of mentoring is beyond the scope of this paper, but we recommend interested readers to examine the DISCCRS Working Group Report on Mentoring for recommendations (http://aslo.org/phd/mentoring.pdf).

Institutional support for faculty: Climate-change research spans across many disciplines, ranging from the historical, to the physical, to the biological, to the social sciences, and ultimately impacts policy decisions. Traditional departmental sources of funding often do not exist for climate-change research, and faculty efforts to secure extramural funding are increasingly competitive. It is essential that universities embrace the interdisciplinary nature of the CCC/P and appropriate the necessary funds to support faculty interested in participating in the CCC/P. Incentives for faculty to design interdisciplinary courses, preferably to be team-taught with faculty members from different departments, would provide an excellent start for the CCC/P. A campus-wide conference or symposium on climate change is another excellent tool to highlight the value of, and publicize, new research based on the CCC/P structure.

Graduation: Graduates from the CCC/P likely will be employed in academia, government, or industry. The academic community needs highly qualified faculty, particularly in newly emerging fields such as climate change, and the CCC/P is an excellent venue for training the next generation of climate-change faculty. The breadth of knowledge gained by graduates of a CCC/P would be well-suited to teaching in undergraduate-only colleges, owing to their broad background, while the experience of interacting with researchers from other disciplines would suit the CCC/P graduates in research universities. The ability to work across traditional disciplinary field also would benefit graduates who are working in government labs, while both interdisciplinary experience and an introduction to science policy would lend graduates of the CCC/P an edge in government or NGO science-policy work. Finally, in the dynamic world of industry, the Working Group believes that CCC/P graduates would have an edge with their broad skill set.

3. Current interdisciplinary Climate Change Ph.D. programs

Strong interdisciplinary programs in climate science or global change maintain a delicate balance of providing core courses to bring students from a variety of backgrounds together and facilitate a basic understanding of core concepts in the field, while simultaneously providing opportunities for exposure to a broad array of interrelated fields in a hands-on capacity. A common thread is for students to develop a strong disciplinary background while always placing their work in the context of other fields. This ultimately leads to new research directions embracing multiple disciplines and impacting societally relevant issues. Below are several program descriptions that highlight some successful programs in climate and global change science. This is by no means an exhaustive list; there are many successful programs. Our intent is to highlight some of the most critical elements of a successful graduate program, that our group has some experience with. These include well-attended seminar series, flexible course designs, internal and external collaborations, and mechanisms for communication among a spectrum of disciplines.

Stanford University, The Earth Systems Program (http://pangea.stanford.edu). The ESP program is currently only available at the undergraduate and master's level, although a Ph.D. program is currently in the works. The program requires students to focus on one of seven areas of study in order to provide the student with adequate depth of knowledge in a particular subject area. However, it also encourages breadth of knowledge by requiring coursework ranging from biology and chemistry to economics and policy. In addition, students are required to complete a

270-hour internship, providing a hands-on, rigorous academic experience working on a supervised project of their choice. The master's seminar course puts students into interdisciplinary teams where they do original research on current environmental issues. It provides a true interdisciplinary research experience, similar to real world problems, particularly in situations where a variety of scientists are asked to evaluate the impact of a proposed policy or provide ideas for addressing an environmental problem.

University of Arizona, The Insitute for the Study of Planet Earth (ISPE, http://www.ispe.arizona.edu/index.shtml). ISPE seeks to provide disciplinary and interdisciplinary research training in the context of the environment of the Earth over both temporal and spatial scales. A main goal of the institute is to forge new paradigms in University partnership with society's decision-makers. Unique opportunities for graduate students include a Ph.D. Minor in Global Change, a Global Change Workshop, and NASA Space Grant Fellowships. The Ph.D. minor provides students with a broad understanding of critical concepts and state-of-the-art skills in the rapidly emerging field of global change. Four courses are required: global biogeochemical cycles, the climate system, the global change workshop, and one elective. Students also include two faculty members from the committee on global change on their dissertation committees and work with them throughout their degree program. The global change workshop provides a forum for investigating global change impacts in an interdisciplinary context. The fellowships are awarded to exceptional students interested in promoting the understanding of space-related research to the public and who are studying in a variety of disciplines ranging from space and earth sciences to public policy as well as global-change related fields.

University of Colorado, Boulder; The Institute of Arctic and Alpine Research (INSTAAR, http://instaar.colorado.edu). INSTAAR facilitates interdisciplinary research specializing in high-altitude and high-latitude regions of the world, as well as non-cold-region Quaternary studies, geochronology, and earth system dynamics. Research is also undertaken to understand the affect of natural and human induced physical and biogeochemical processes on the local, regional, and global scales. INSTAAR'S Teaching Mission is directed towards fostering an appreciation and understanding of the biological, chemical, and physical processes operating in continental and ocean environments. INSTAAR students are registered for degree programs in an appropriate department and college, such as Engineering, Biology, Geography, Geological Sciences, and Atmospheric and Ocean Sciences, for their primary coursework and teaching experiences, while maintaining their primary research home with INSTAAR. Students benefit from affiliation with INSTAAR by being exposed to interdisciplinary classes and research opportunities, field work opportunities, 30 scientific laboratories and facilities, the Mountain Research Station, international educational experiences, and volunteer outreach opportunities. Students also profit from a weekly colloquium by INSTAAR scientists or invited scientists, as well as a weekly Graduate Student Seminar Series.

National Science Foundation's Integrative Graduate Education and Research Traineeship (IGERT) Program (http://www.nsf.gov/home/crssprgm/igert/start.htm, http://atlas.islandinstitute.org/igert/). The IGERT program has been developed to meet the challenges of educating U.S. Ph.D. scientists, engineers, and educators with the interdisciplinary backgrounds, deep knowledge in chosen disciplines, and technical, professional, and personal

skills to become in their own careers the leaders and creative agents for change. The program is intended to catalyze a cultural change in graduate education, for students, faculty, and institutions, by establishing innovative new models for graduate education and training in a fertile environment for collaborative research that transcends traditional disciplinary boundaries. It is also intended to facilitate greater diversity in student participation and preparation, and to contribute to the development of a diverse, globally-engaged science and engineering workforce. The program comprises approximately 100 award sites across the country in areas of academic interest including biological sciences, computer and information science and engineering, engineering, geosciences, mathematical and physical sciences, and social, behavioral and economics. Ph.D. students awarded IGERT fellowships receive stipend and tuition support, plus funds for research materials, which varies for each program.

4. Conclusion

The training of the next generation of climate-change researchers is of utmost importance as climate change and its associated impacts take on increasing local, regional, and global relevance. This report seeks to address this issue by highlighting aspects of a successful climate-change Ph.D. program; a program which seeks to balance traditional disciplinary training with exposure to the broader, interdisciplinary climate-change community. While the heart of any Climate Change Center/Program (CCC/P) lies in the motivation of the students, the dedication and mentoring of the faculty, and the existence of strong institutional support, it is equally critical that the structure of the program remains flexible and allows for individual creativity and growth. The creation of a CCC/P, as envisioned by the Working Group, will have a number of benefits for society and for climate-change research as a whole; it will better prepare recent graduates to communicate their research in climate-change science to the public and policy makers, it will help facilitate collaboration amongst researchers from fields that traditionally do not have strong ties, and it will likely improve job placement for graduates of these Centers or Programs. As the current academic system evolves to face the increasingly interdisciplinary and interconnected nature of the world we live in, The Working Group is hopeful that next generation of climate-change scientists produced by Climate Change Centers/Programs, such as described above, will be better prepared to contribute to the debate and conversation associated with this important societal concern.

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