

Proposal for a Doctorate Degree in Climatology

College of Earth, Ocean, and Environment

September 2013

1. Program Description

The science of Climatology seeks to improve our understanding of the varying and changing thermal and moisture states of our environment, and of those natural and human-influenced processes and events that affect those states. Climatic processes are essential to maintaining the global biosphere, including a land surface of which the great majority is considered habitable, as well as to many related physical phenomena such as ocean currents and surface erosion. It is a science rooted in an understanding of the atmosphere but inseparable from the rest of the global system.

The Ph.D. in Climatology trains students to do research on Climatology in any of these areas. While a certain core of training in atmosphere-centered climatology is expected, the primary background of incoming students may be in one of the related fields. The universal expectation will be of a dissertation project that uses state-of-the-art methods of data gathering, data analysis, or modeling to study a climatological question that is simultaneously original, significant, and current. Besides becoming deeply familiar with a topical area, graduates must also become professionally adept at their primary research technique (e.g., statistical methods for data analysis, numerical modeling).

Our primary benchmark for success will be our ongoing success placing graduates in positions for which a research Ph.D. is a primary credential, including research postdocs, university professorships, and positions in the private sector and government. Prompt publication of doctoral dissertation results in high quality journals will also be taken as a sign of success.

The only implementation required for this Ph.D. program is the establishment of an *Academic Council*. The duties of the Academic Council will be to recommend admission of students, develop plan of courses for newly matriculated students, evaluate the progress of ongoing students, and to approve and evaluate the qualifying examinations. With the approval of the Dean and Academic Council of CEOE, the core faculty of the program may, in the future, establish bylaws that lay out more specifically the composition and duties of the Academic Council. As an *initial committee*, we envision a committee of five regular faculty members of CEOE, in which: (1) the chair of the committee will be the Chair of the Geography Department (This is only to begin the program and to honor where the Climatology Ph.D. originated.), (2) one member will be either the Director of POSE or a designee of the Director of POSE, (3) and three others with their primary appointment in CEOE. Initial membership on the committee will be proposed by the Chair of Geography and approved by the Dean of CEOE. The committee may then establish a system of terms and rotation by which various interested faculty members may serve without making indefinite commitments.

2. Rationale and Demand

The Ph.D. program proposed here is new only in an administrative sense. This proposal seeks to replace the current concentration in Climatology of the Geography Ph.D. That concentration, in turn, came into existence in 2008 as a revision of an earlier Ph.D. in Climatology that was housed entirely in the Geography Department. A separate, contingent proposal from the Geography Department covers the changes in concentrations of the Geography Ph.D.

Since the mid-1980s, the Geography Department of the University of Delaware has produced over 40 Ph.D. graduates in Climatology or Geography with a Climatology concentration. That program was built on a preceding decade of graduate education at the masters level, also focused on climatology. The original mission reflected the visions of our department's four climate-oriented faculty members at the time (around energy-budget, water-budget, synoptic and applied climatology), and focused on atmospheric effects at the land surface. This program began at a time when climatology was considered variously a subfield of geography or of meteorology, and it was not a field widely known outside of academia and agricultural extension services.

Public awareness of climate has grown well beyond the imagination of those who entered the field just a few decades ago. Questions about climate change and its causes and implications are among the central environmental questions of our time. Climate change drives the research agendas of a large fraction of all scientists who have a primary interest in climate, earth, oceanic, and environmental sciences. Since its cause is inextricably linked to energy policy and it has effects across the gamut of human activity, it is a central issue for a wide range of geographers, social scientists, policy specialists, and economists. We have reached a level of awareness wherein questions about climate change and related policy arise in debates among candidates for President of the United States. Reports of the National Academy of Sciences and the Intergovernmental Panel on Climate Change have regularly reaffirmed that this is a topic of great and ongoing concern.

The Climatology program within the Geography Department has also changed since its inception, as must any program that hopes to stay current with a research Ph.D. Technological changes have given us greater access to a wider variety of data sources, numerical models, and analysis techniques, such that less time is spent on the “background” or “overhead” aspects of research. As we have expanded as a department, revisions were made in 2008 to allow greater interaction between the climatologists within the department and those who focused more on land surface or hydrological processes, reflecting the importance of such boundary conditions on climatic understanding. We remain an active program, with four Ph.D.’s granted in the past two years, leading to three assistant professorships and a postdoc at a DOE national lab.

Three years ago, as part of the environmental initiatives associated with the University’s Path to Prominence, the Department of Geography joined with the Department of Geological Sciences and the School of Marine Science and Policy to form a new College of Earth, Ocean, and Environment. Now we would like to reconfigure the Climatology Ph.D. program to make better use of the opportunities afforded by this new college. We propose returning the Ph.D. in Climatology to its pre-2008 status as an independent Ph.D. program, while also opening it to a wider group of faculty. The program would continue to be *administered* by the Geography

Department, but would now be considered a college-wide program, allowing full faculty participation by any member of the College of Earth, Ocean, and Environment. This change would keep the existing faculty resources within the Geography Department and make the program more suitable for use by members of the School of Marine Science and Policy within which many projects already contain some element of atmospheric science.

The Department of Geography has eight faculty who regularly teach and are actively involved in climatological research. The faculty are listed below identifying their sub-discipline expertise:

Claessens, Luc (Assistant Professor) Ecohydrology
DeLiberty, Tracy (Associate Professor) Physical and hydroclimatology
Hanson, Brian (Professor) Climate dynamics
Leathers, Daniel (Professor) Synoptic climatology
Legates, David (Professor) Hydroclimatology
Levia, Delphis (Associate Professor) Boundary layer energy and moisture exchanges
Rauscher, Sara (Assistant Professor) Regional climate dynamics and modeling, climate change
Veron, Dana (Associate Professor) Land surface-atmosphere interactions, clouds and radiation

The School of Marine Science and Policy include seven faculty whose research and teaching includes aspects of climate science:

Archer, Cristina (Associate Professor) Meteorology, wind power
Billups, Katharina (Associate Professor) Oceanography
Firestone, Jeremy (Associate Professor) Wind power science, engineering and policy
Kirwan, Denny (Professor) Ocean dynamics
Kukulka, Tobias (Assistant Professor) Ocean fluid dynamics, wind and water interactions
Muenchow, Andreas (Associate Professor) Physical oceanography
Veron, Fabrice (Associate Professor) Air-sea interactions

And the Geological Sciences Department has one faculty, Michael O'Neal (Associate Professor), whose research and teaching revolve around paleoclimatology.

The proposed Ph.D. in Climatology would keep most of the characteristics of its predecessors, including entrance requirements of a master's degree and significant science and technical preparation. We see this as a science Ph.D. that takes a very broad view of climatology, but an adamant stand for high quality research output and technical preparation. As noted above, the primary responsibility for administration of this program will remain within the Geography Department. Admissions and funding decisions will be shared with participating faculty via an Academic Council with the intention that students will be housed and funded within the academic unit of their intended primary adviser.

Many of the questions regarding initiation of a new program are obviated by the current existence of the Geography Ph.D. concentration in Climatology. We have a program that currently receives good applicants, graduates and places good students, and contributes to the research missions of our College and University. Rather than being a truly new program, we see

this initiative as the latest evolution of a successful program of Ph.D. education that granted its first degree in 1986 and should continue for decades to come.

3. Enrollments

The Geography Department graduate programs (M.A., M.S. and Ph.D.) consistently enroll 30-40 graduate students. Of this total, roughly one-third are seeking a Ph.D. in the climate field, and the majority of these Ph.D. students began graduate work in our M.S. program.

Admission to the Ph.D. requires the completion of a master's degree. A GRE verbal and math score of 300 or higher (or for the old GRE exam taken prior to August 2011, a combined GRE score of at least 1100) is also expected, and the undergraduate record will be examined. However, the focus of Ph.D. admission is on the quality of work at the master's level. The field of the master's degree will most commonly be geography, geology, atmospheric science, oceanography or environmental science, but students from other sciences, engineering, and the social sciences are encouraged to apply. Applicants will be judged on the basis of both the quality and the range of their education. Requirements of specific mathematical background (calculus through ordinary differential equations) and of computer analysis and programming skills will be required prior to admission, whereas deficiencies in the topical core discussed below may be taken care of by course work during the degree program. In addition, the applicant's research interest must show topical compatibility with areas of research by potential advisers.

Students completing a M.S. degree within CEOE who wish to continue towards the Climatology Ph.D. must submit a Change of Classification Form to the Academic Council. The faculty will evaluate these as they are received, and consider input from the student's masters committee, without particular deadlines. Students completing master's degrees from UD outside of CEOE who wish to enter the Ph.D. program must complete a regular admission application as if entering the program from outside the university.

4. Curriculum Specifics

The Climatology Ph.D. normally requires at least three academic years of graduate work. Students are expected to be in residence (enrolled full-time) for at least two continuous years beyond the master's degree. Students are expected to acquire general knowledge of climatology, including physics of climatology (thermodynamics, radiation, and cloud processes), atmospheric dynamics (forces and flows), measurement (microclimatological methods and instrumentation, remote sensing) and computational methods for data analysis and synthesis. Most of this background will typically be acquired through coursework at the undergraduate or master's level. Students will demonstrate general knowledge during a qualifying written examination, normally taken during the second year. The Academic Council of the Ph.D. program will approve the examination, and at least two-thirds of the time and effort on this examination will be devoted to the general knowledge of climatology. The student's adviser and committee may contribute questions related to the specific subfield engaged in by the student for the remainder of the examination.

A suite of regularly taught climatology courses covers the basic range of atmospheric science and climatology. The first six courses listed below constitute the *core background*; those areas expected during the *written qualifying* examination.

Geog612	Physical Climatology
Geog622	Atmospheric Physics
Geog623	Atmospheric Dynamics
Geog653	Synoptic Climatology
Mast809	The Ocean & Climate Variation
Geog651	Microclimatology
Geog656	Hydroclimatology
Geog657	Climate Dynamics
Geog658	Paleoclimatology
Geog652	Seminar in Climatology
Mast662	Climate Change: Policy, Equity and Mitigation
Mast853	Oceanography Seminar
Mast882	Physical Ocean Science and Engineering Seminar

Methodological courses listed below provide the groundwork for our graduate students along with additional courses in statistics, computer science and engineering.

Geog604	GIS for Environmental Research
Geog605	Computer Programming for Environmental Research
Geog670	Geographic Information Systems and Science
Geog671	Advanced GIS
Geog672	Seminar in GIS
Geog677	Spatial Data Analysis
Mast606	Atmosphere and Ocean Remote Sensing
Mast669	Statistics for the Marine Sciences
Mast681	Remote Sensing of Environment
Mast691	Ocean Fluid Dynamics
Mast806	Geophysical Fluid Dynamics I
Mast811	Oceanographic Time Series Analysis
Mast817	Research Design and Methods
Stat657	Statistics for Earth Science

In addition to the core knowledge, *specialized knowledge* is required in two areas, one of which is *topical* (covering the specific research area) and the other being in *technical* methods. Typical technical methods include graduate course work in statistics, mathematics, computer science, or related sciences that are relevant to the area of research of the dissertation. Determining that a suite of courses adequately fulfills these requirements is the responsibility of the student's Advisory Committee.

Each student must enroll in at least nine credits of *CLIM969 Doctoral Dissertation*. Enrollment for these credits is allowed only after achieving candidacy status. The doctoral dissertation must

be original research contributing to knowledge following the traditions of the scientific method. This research is conducted by the candidate in collaboration with the Advisory Committee. Leadership and clear contributions to scientific knowledge must be demonstrated by the candidate. The dissertation must not be based solely on literature review, but include new data collection, data analyses, experimentation, and/or modeling. A typical understanding of “contribution to knowledge” is that the dissertation reports on work suitable for publication in high-quality, refereed scientific journals. When the dissertation project has been fully designed, the adviser and student will schedule an *oral comprehensive* examination of the dissertation proposal with the entire Advisory Committee. Besides determining that the proposed work, if successfully carried out, constitutes a reasonable dissertation project, they will evaluate if the skills and knowledge acquired from courses and other work are sufficient for the intended project.

The Ph.D. Advisory Committee consists of four to six members who evaluate the program of courses, the comprehensive examinations, and the doctoral dissertation. The adviser must have established a record of scholarship in the field of the dissertation and be a member of the faculty of CEOE at the University of Delaware or professional staff that hold secondary faculty appointments within CEOE. A minimum of three additional members of the committee must fill the following categories: one will be another member of CEOE from within the topical area of concentration, one will represent the secondary area of study (usually the methods or technical area of study), and one will be an external member. The external member may be from outside the University in order to broaden the perspectives of the committee or the external member may have a primary appointment in a University of Delaware department outside of CEOE. The external member is a full, voting member of the committee.

Additional details outlining the doctoral program requirements and deadlines are found in the accompanying Climatology Graduate Program Policy Handbook.

6. Resources

All resources needed are in place for the current Climatology concentration of the Geography Ph.D.

7. Evaluation

Evaluation of graduate students occurs each winter with students filling out a self-study and planning form. This document is reviewed by the Academic Council in consultation with each student’s adviser, and each student will receive a response from the committee, assessing progress and providing recommendations and objectives for the upcoming year.

As noted above, the learning goal of this program will be to produce climate scientists capable of ongoing research. Achievement of this goal will be assessed by ongoing evaluation of placement of graduates in academic and research positions, publication of dissertation-related resources and

continued attraction of high quality graduate students. The administration regularly monitors its graduate programs on these bases.

8. Draft Catalog Entry

Found in attached Academic Program Approval Form