GRADUATE STUDENT HANDBOOK

FOR THE SCHOOL OF

EARTH AND ATMOSPHERIC SCIENCES

GEORGIA INSTITUTE OF TECHNOLOGY

Doctoral and Master's Programs

This Handbook, prepared by the School's Graduate Studies Committee, states the policies and procedures of the School of Earth and Atmospheric Sciences. All rules and policies of the Institute take precedence in any conflict, real or apparent, with statements contained herein.

Latest Revision February 2026 with old and new Comprehensive Examination

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I. General Student Information

Permanent (Thesis) Advisor

Prior to enrolling in the graduate program, all incoming students are assigned a *Temporary Advisor* who will assist the student with registration during his/her first semester of study and will help the student select a *Permanent Advisor*. The *Permanent Advisor* will also be the *Thesis Advisor* for the student's Thesis research. Hereinafter the term *Advisor* will be used to designate the Permanent or Thesis Advisor.

Each student must select an Advisor and major field of study by the end of their first semester of residence in order to register for succeeding semesters. The Advisor must agree to serve as such, and the agreement will be signified by a signed form (see attached sample in Appendix). The *Advisor Form* will be incorporated into the student's file. A newly signed Advisor Form must accompany any subsequent change of Advisor.

The advisor-student relationship is fundamental to a student's success in graduate school. In recognition of this, confidential and impartial resources are provided to graduate students by both the School of Earth and Atmospheric Sciences (EAS Graduate Coordinator and Chair) and the Institute (http://www.provost.gatech.edu/reporting-units/conflict-resolution-ombuds).

Evaluation of Progress

Each student must complete and submit an updated *Graduate Student Annual Report* (GSAR) by April 15th of each year (Instructions provided in GSAR). Within a month after GSAR submission, the student should meet with their advisor to discuss their coursework, research, and service accomplishments during the current academic year and expectations for the following year. These accomplishments and expectations are reported in the *Advisor Evaluation Form* that is then submitted by the student to the Graduate Coordinator. The GSAR report is used by the EAS *Graduate Coordinator* to ensure that satisfactory progress is being made towards the degree and to help determine whether the student receives continued financial support. If the GSAR has not been completed, a hold will be placed on the student's registration for courses. The student may be asked to meet with the Graduate Coordinator and/or the EAS Graduate Studies Committee, as appropriate, to discuss their progress and determine what actions need to be taken.

Course Registration

All M.S. and Pre-Comps Ph. D. students must have their *Registration Form* approved by their Advisor and the Graduate Coordinator to remove the Hold on their Registration. The faculty member responsible for supervising a Special Problems Course must approve the Registration Form of each student registering for that course.

Graduate Assistants must be full-time students and must register for at least 12 hours of course work on a letter-grade or pass/fail basis. With permission, up to three hours may be taken as Audit. These students must maintain a full-time (12-hour) course load. Dropping to below 12 hours after registration, unless approved in advance by the Graduate Coordinator, will result in termination of financial support. Students are encouraged to register for more than the minimum of 12 hours credit, either by taking thesis hours or special problems.

Academic Standing

The academic standing of a graduate student is based on both the most recent academic term and the cumulative Grade-Point Average (GPA). The minimum satisfactory GPA is 2.70 for M.S. students and 3.0 for Ph.D. students. Students who are not on academic probation are in good academic standing. A student who has a cumulative GPA below the minimum satisfactory is put on academic warning, a subcategory of good academic standing. A student on academic warning will be deemed in good academic standing and removed from academic warning if both the GPA for the current academic term and the cumulative GPA are above the minimum satisfactory requirement. Doctoral students will also be placed on academic warning if they receive an unsatisfactory grade in research (EAS 9000).

A student on academic warning whose GPA is below the minimum satisfactory scholarship requirement for any academic term shall be placed on academic probation. Doctoral students will also be placed on academic probation if they receive an unsatisfactory grade in research for two consecutive terms of enrollment. A student on academic probation will be deemed in good academic standing and removed from academic probation if both the GPA for the academic term and the cumulative GPA are above the minimum satisfactory scholarship requirement.

The Institute may drop from the rolls at any time a student whose record in scholarship is unsatisfactory, including a graduate student whose GPA for any term is below 2.00. A student on academic probation whose GPA for the academic term of probation is below the minimum satisfactory scholarship requirement and whose cumulative GPA is below the minimum satisfactory scholarship requirement shall be dropped from the rolls for unsatisfactory scholarship. The record of a student on academic probation whose GPA for the academic term is unsatisfactory, but whose overall academic record is satisfactory, may be reviewed by the Institute Graduate Curriculum Committee. The student may be dropped or continued on academic probation.

Financial Support

The annual stipends for all Graduate Assistantships (GRAs and GTAs) are set by the faculty of EAS and published before the start of Fall Semester. To continue to receive financial support, a student must maintain a GPA of 3.0 in EAS courses and remain in good standing with the School and Institute. The Graduate Coordinator will review the file of any student failing to meet these requirements and, in conjunction with the Graduate Studies Committee, may recommend to the *School Chair* that financial support be terminated.

A student requesting support from the School as a Graduate Teaching Assistant should fill out the *TA Request Form* provided by the TA coordinator by the middle of the semester prior to that during which TA support is desired. For students seeking TA support in Fall, this request should accompany the GSAR. Students working towards a Ph.D. degree normally will not be given GTA/GRA support beyond **five** years of study. Students working towards a M.S. (Thesis) degree normally will not be given GTA/GRA support beyond **two** years of study. Students working towards a M.S. (non-Thesis) degree are not normally eligible for Graduate Assistantship support.

Graduate Assistantships are normally half-time (1/2) appointments (20 hours/week) in the Institute. One-third (1/3)-time appointments are permitted only upon written approval of the Advisor, the Graduate Coordinator, the Graduate Studies Committee, and the School Chair. One-half time Graduate Assistants cannot simultaneously be employed at any other job. A one-third time Graduate Assistant cannot be employed for more than 7 hours/week at any other job without the approval of his/her Advisor and the Graduate Studies Committee.

Graduate Teaching Assistants

First time GTAs are required to take CTL 8000 GTA Preparation (EAS section), a one credit pass/fail course that introduces students to the procedures and practical skills needed to be an effective graduate teaching assistant.

Honor Code

The School of Earth and Atmospheric Sciences strictly enforces the Honor Code of the Institute.

English Proficiency

Students whose speaking, writing and reading skills in English are not satisfactory upon entering must achieve English proficiency by the end of their first year in the program.

II. M.S. PROGRAM REQUIREMENTS

Designated and Undesignated Degree

The School of Earth and Atmospheric Sciences offers two M.S. Degrees: (1) the **Designated Master's Degree** (thesis program) which leads to a M.S. in Earth and Atmospheric Sciences and requires completion of a Master's thesis and (2) the **Undesignated Master's Degree** (non-thesis program) which leads to a M.S. degree. The thesis program is strongly encouraged. The non-thesis degree option requires the permission of the School Chair.

EAS Academic Requirements

The Institute's credit hour requirements for both the Thesis and Non-Thesis Master's degree are explicitly stated in the Georgia Tech General Catalogue. In addition to the Institute requirements, EAS requires students pursuing a non-thesis master to take three credit hours of special problems (EAS 8901).

Students pursuing the thesis option must submit a thesis based on their research accomplishments to the Thesis Reading Committee (TRC). This committee consists of at least three faculty members including the student's advisor. Students may submit their final version of their thesis to the library after it has been signed and approved by the TRC.

General requirements for both options include a minimum of 30 credit hours. All courses must be at the 4000 level or above. A minimum of 12 EAS course credit hours must be taken for a letter grade at the 6000 level or above. A summary of minimum course requirements for both the thesis and non-thesis options are given below.

	thesis	non-thesis
EAS course credit hours (graded) at 6000-level or above	12	12
Elective credit hours in major area at 4000-level or above	6	6
Elective course credit hours at 6000-level or above	0	9
Special Problems – EAS 8901	0	3
Undesignated credit hours (may include thesis hours)	6	0
EAS 7000 (M.S. thesis credit hours)	6	0
Total credit hours	30	30

A maximum of 3 course credit hours may be taken under the pass/fail (P/F) designation. EAS 7000 is only taken on a pass/fail basis and cannot be used to fulfill the credit hour requirement for a non-thesis degree. Finally, EAS 6000 and CETL 8000-EAS cannot be used to fulfill the degree requirements.

GT Responsible Conduct of Research (RCR) Requirement

The RCR Academic Policy for Master's Thesis Students applies to all master's students who register for thesis hours (courses numbered 7000). Applicable master's students, as part of their degree requirements, must complete at least one of the following (see http://www.rcr.gatech.edu/masters-policy):

(1) Successfully complete an online CITI RCR course (http://www.rcr.gatech.edu/online-training)

OR

(2) Successfully complete a doctoral-level RCR course (http://www.rcr.gatech.edu/doctoral-courses) that satisfies the in-person RCR training requirement for doctoral students. The latter requirement is satisfied by taking the EAS graduate professional preparation course "Introduction to Research and Responsible Conduct" (EAS 6000; see Professional Preparation Requirement for PhD).

The RCR training must be completed and verified before the Request for *Approval of Master's Thesis Topic Form* will be processed by the Office of Graduate Studies. Important: Master's thesis students who plan to transition to a doctoral program are strongly encouraged to complete the First Option and the Second Option above (see http://rcr.gatech.edu/doctoral-policy).

Transition to the Ph.D. Program

Students who want to transition to the Ph.D. program must petition the Graduate Studies Committee. The petition must be accompanied by a supporting letter from their Advisor. If the petition is accepted, the student must file a *Change of Major/Level Form* for Graduate Students (https://registrar.gatech.edu/info/change-majorlevel-form-graduate-students) and submit the form to the Registrar with the appropriate signatures.

III. Ph.D. PROGRAM REQUIREMENTS

All Ph.D. students must fulfill the EAS Course, Academic Breadth and Professional Preparation requirements along with the Georgia Tech (GT) Minor Course and Responsible Conduct of Research requirements. In addition, the student must pass the Comprehensive Examination. To complete the Ph.D., the student must complete the Minor requirement, write their Doctoral Dissertation, and successfully defend it before the Final Doctoral Examining Committee. A checklist of the required steps for the Ph.D. is provided in the Appendix along with the necessary forms.

EAS Course Requirements

Ph.D. students must complete at least 15 credit hours on a letter grade basis of EAS courses at the 6000 level or above. Seminar classes, special problems courses, and thesis hours cannot be counted towards this total. Special topics classes may be credited to this total with approval of the Graduate Coordinator.

GT Minor Course Requirement

The Institute requires doctoral students to complete at least nine semester hours of work in *related* letter grade courses outside the student's Ph.D. research area (defined as one of the primary research areas listed on the EAS web page). The minor field can consist of courses from more than one School, as long as the courses are related. Students are allowed to use EAS courses to satisfy this requirement (e.g., a student performing research in geochemistry could satisfy the minor requirement with geophysics courses). Additional details are found in the Institute catalog. In certain cases, incoming Ph.D. students with prior graduate training (i.e., M.S. degree) may apply previously earned graduate credit hours toward the minor requirement. In all cases minor course credit hours will not count toward fulfillment of the 15 credit EAS course requirement. The student's plan for satisfying the minor field requirement must be submitted using the *Doctoral Minor Form* (https://grad.gatech.edu/theses-dissertations/forms) and approved by the EAS Graduate Coordinator prior to the completion of the comprehensive examination. Once the student has completed the minor requirement, the EAS Graduate Coordinator sends a confirmation, accompanied by course grades, to the Institute Graduate Office for final approval and recording.

GT Responsible Conduct of Research (RCR) Requirement

The Georgia Tech RCR Academic Policy for Doctoral Students applies to all doctoral students. This Academic Policy includes master's students who have since transitioned to a doctoral program. Adhering to this Policy satisfies the requirements of the RCR Compliance Policy (http://www.rcr.gatech.edu/doctoral-policy).

As part of their degree requirements, doctoral students must complete two forms of RCR training:

(1) Online Training

An online CITI RCR course must be successfully completed within 90 days of when applicable students begin the first full semester in their doctoral program (http://www.rcr.gatech.edu/online-training).

AND

(2) In-Person Training for Doctoral Students

The latter requirement is satisfied by taking the required EAS professional preparation course "Introduction to Research and Responsible Conduct" (EAS 6000) discussed below (in Professional Preparation Requirement) or PHIL 6000 (http://rcr.gatech.edu/phil6000).

EAS Academic Breadth Requirement

In recognition of the increasing interdisciplinary nature of research in Earth and Atmospheric Sciences, the EAS Ph.D. program incorporates an academic breadth component. This requirement, which provides students with a broader context for their own disciplinary research, is satisfied by fulfilling at least one of the following three options:

(1) The student spends one semester as a Graduate Teaching Assistant for EAS 1600, 1601, or 2600. Participation in this option requires lecture attendance.

(2) The student chooses an internal (EAS) minor track to satisfy the Institute minor requirement (discussed above). As per Institute requirements, the internal minor must be distinct from the student's specific Ph.D. research area. Example cases include:

a) An atmospheric chemistry student pursuing an internal minor in remote sensing

b) A climate dynamics student pursuing an internal minor in environmental chemistry

c) A counterexample: An atmospheric chemistry student is not allowed to pursue an internal minor in air quality (which is insufficiently distinct).

This option is generally not available to incoming students who choose to satisfy the Institute minor requirement using prior graduate training outside of Earth and Atmospheric Sciences (For example, an incoming student with an M.S. in physics who chooses to minor in physics on the basis of previous graduate coursework).

(3) A third option is available to students who prefer not to pursue either the teaching assistant or internal minor options. Students selecting this option must take 2 or more EAS courses (one at the 3000 level or above; the second at the 6000 level or above) from research areas outside the student's Ph.D. research area. As an example, a geophysics student could take courses in climate dynamics and geochemistry to fulfill this requirement.

In all cases the student's plan for satisfying the academic breadth requirement must be included in the GSAR and approved by the Graduate Coordinator prior to taking the comprehensive exam.

EAS Professional Preparation Requirement

All Ph.D. students are required to take the professional preparation course "Introduction to Research and Responsible Conduct" (EAS 6000) during their first year in EAS. This one-hour seminar course is intended to give incoming students a general overview of the breadth and depth of research in the School of Earth and Atmospheric Sciences as well as a general discussion of expectations for graduate students. This discussion includes several sessions related to ethics in scientific research as well as short exercises in effective science communication. Throughout the semester there will be opportunities to inform students of relevant fellowship opportunities, procedures, and deadlines.

The primary aim of this course is to identify and discuss ethical challenges that EAS graduate students confront in their research and to give incoming graduate and master students an overview of the research areas covered in the School.

Topics addressed include those recognized by NIH, NSF, and Georgia Tech as crucial to being a responsible researcher.

The structure of the course is as follows:

The course will consist of eleven lectures, each 50 minutes long, introducing students to key background concepts and issues in the realm of research ethics. Four more classes will be devoted to introduce the research areas covered by EAS faculty members.

——To receive a passing grade, each student must attend the entire course. Students will have to be in attendance for at least 9 of the 11 hours devoted to RCR, and to 3 of the 4 classes devoted to the EAS research overview.

Students will work in groups of 2-3 (depending on enrollment) towards a poster or PowerPoint presentation open to the whole School to be delivered at the end of the course. The presentation will be about a RCR case in disciplines relevant to research areas within EAS.

Comprehensive Examination for Students First Enrolled <u>Before</u> Fall 2026

The Comprehensive Examination consists of a thesis proposal and a two-step written and oral examination. The written examination is composed of a series of problems formulated by the student's examining committee. The oral examination covers the subject matter of the thesis proposal, written examination and other general knowledge in the student's research field.

Each student must select a permanent thesis advisor and major field of study prior to the end of his/her first semester. The student will be provided with academic guidelines for the chosen major field of study. The guidelines will include a recommended sequence of courses and a summary list of Essential Knowledge for the major field of study. The Essential Knowledge Lists (EKL) for major EAS disciplines are provided in Appendix.

The Comprehensive Examination Committee (CEC) must be formed for each student by September 15 following the first full year in residence. The CEC will consist of the student's permanent advisor, two academic faculty members chosen by the student from the student's Thesis Advisory Committee, and two academic faculty members appointed by the Graduate Studies Committee (GSC). One of the GSC appointed members will be the committee chair and the other from a research area outside the student's area. The student's selections must be reported to the GSC no later than April 15 following the first full semester in residence. Thereafter, the student, in collaboration with his/her advisor, will formulate (a) a thesis proposal abstract and (b) an Essential Knowledge list (based on the student's thesis research area). Students may adopt one of the existing Essential Knowledge lists for major disciplines or develop a tailored list by expanding upon the discipline's existing Essential Knowledge list.

By September 1st following the first full year in residence, the student, in agreement with their advisor, must communicate to the GSC if they intend to proceed to the comprehensive exam the following Spring or Fall semester. The thesis proposal abstract and Essential Knowledge list must then be submitted to, and approved by, the CEC prior to the end of the Fall semester or prior to the end of the following Spring semester, following the first full year in residence (summers excluded), respectively.

If a student is unable to meet this deadline, they will be required to complete a thesis M.S. degree within EAS (prior to the end of the succeeding summer semester) in order to proceed to the comprehensive exam. Students transitioning from a thesis M.S. degree to the PhD program must take the comprehensive exam no later than the Spring Semester of their third year in residence.

The thesis proposal should be in the general area of the student's PhD thesis research and must incorporate all of the following four elements:

a) <u>Scientific background and motivation</u>. This element must provide a critical review of relevant past literature and how the student's new results and proposed future research relate to these previous research efforts by other scientists.

b) <u>Preliminary research</u>. New research results are presented and interpreted in this element.

c) <u>Synthesized discussion/conclusions</u>. The student must provide a synthesizing summary discussion of his/her new research that assesses the (i) immediate scientific implications of the new research, (ii) broader impacts, and (iii) remaining scientific questions to address.

d) Future research plans. The student must provide a detailed and structured overview of his/her future research plans in this element.

The paper will be evaluated on the basis of its scientific quality, thoroughness, and clarity.

Scientific discussions with faculty members during the development of the thesis proposal are permitted and strongly encouraged. This includes topic selection, reference materials suggestions, and general outline development. Although faculty may provide feedback to students regarding their research results, the thesis proposal must be the work of the student and *faculty members are not permitted to directly contribute to the creation or editing of the thesis proposal document*. However, the student is permitted and strongly encouraged to obtain input from other students regarding matters of clarity, style and grammar. Citation of source materials is mandatory, and plagiarism will result in failure of the examination.

The manuscript body (abstract, text and figures) is limited to 35 pages; longer documents will not be accepted for review by the CEC. The text must be double-spaced with a minimum font size of 12 point and 1-inch margins. Each paper must be single-sided and include an abstract and a table of contents. Figures (with captions) shall be placed in sequence at the end of the paper and references should be formatted using either American Meteorological Society or American Geophysical Union journal specifications. The reference list is not included in the page limit.

The thesis proposal must be submitted to the CEC by March 1 (for Spring semester exams) or by September 1st (for Fall semester exams) following the third or fourth full semester in residence in the Ph.D. program (summers excluded). The paper will then be evaluated by the CEC with each committee member providing a written review to the committee chairman. The written examination will take place during the week prior to Spring Break or during the third week of September and will be followed by an oral examination scheduled (by the student) to take place no later than April 15 (normally occurring in the two weeks following Spring Break) or October 15, respectively.

The written examination is a one day, closed-book exam consisting of a collection of 5 synthesizing problems formulated by each respective CEC member based on the student's thesis proposal and Essential Knowledge list. The problems are aimed at assessing the adequacy of the student's foundational knowledge base within his/her research field. Each student is required to answer 4 out of the 5 problems. The subsequent oral examination will consist of two parts. The first part is a 25-30 minute public presentation of the thesis proposal to the examining committee and other interested faculty and students. Students who have not yet taken the comprehensive examination are especially encouraged to attend the oral presentation and the following 5-10 minute open question period, during which the student will answer questions from the general audience. The second part of the examination is a closed session in which members of the CEC will question the student regarding the thesis proposal, written examination, and other general knowledge in the student's chosen research field. The entire oral examination takes about 3 hours. After the closed session is completed, the student will be excused while the examining committee votes on the outcome of the examination. A pass vote from 3 of 5 CEC members is required for successful completion of the comprehensive examination. The student will be notified immediately of the outcome. Students receiving a conditional pass will be asked by the CEC to satisfy an additional requirement within a timeline established by the committee. Students who fail the exam will not be advanced to candidacy in the Ph.D. program. In the event of failure, the CEC will also provide the student with a recommendation on how to proceed forward. Students who pass the exam are advanced to candidacy upon submission of the Institute *Request for Admission to Ph.D. Candidacy Form*. In all cases the student shall receive a summary document reviewing the findings and recommendations of the CEC.

Timeline of Comprehensive Examination for Students Enrolled Before Fall 2026

Schedule	
Fall, First year	Student chooses a permanent academic advisor and the major field of study by the end of Fall Semester. *Student selects the major field of their Ph.D. research.* *Depending on the selected field, students are provided with guidelines regarding the recommended sequence of courses (including required course on Scientific Writing) and Essential Knowledge Lists (developed for each major discipline).*
Spring, First year	Student selects two members (in addition to their advisor) of their Comprehensive Examination Committee (CEC) by Apr. 15.
Summer, First year	Student and their advisor tailor the Essential Knowledge list in accord with the student's thesis research area
Fall, Second year	By September 1^{st}, the student, in agreement with their advisor, requests to take the Comprehensive Examination in the <u>Spring</u> of their 2^{nd} year or <u>Fall</u> of their 3^{rd} year. CEC for all students are formed by September 15th <u>For students taking Comprehensive Exam in Spring of second year</u>: Student requests CEC approval of their abstract of the thesis proposal and the student's Essential Knowledge List (Submit documents to CEC prior to November 15; obtain summary feedback from CEC Chair prior to the end of Fall Semester).
Spring, Second year	<u>For students taking Comprehensive Exam in Spring</u>: Student submits their thesis proposal (by March 1); Two step examination process follows (details on next page) <u>For students taking Comprehensive Exam in Fall</u>: Student requests CEC approval of their abstract of the thesis proposal and the student's Essential Knowledge List (Submit documents to CEC prior to April 1; obtain summary feedback from CEC Chair prior to the end of Spring Semester of Second year).
Fall, Third year	<u>For students taking Comprehensive Exam in Fall</u>: Student submits their thesis proposal (by September 1); Two step examination process follows (details on next page) If a student is not ready for the examination, they must complete a thesis M.S. by the end of Fall Semester of the third year.

Exam structure	Two-step Examination Process: 1. Take written examination (one day during the week prior to Spring Break, or during third week of September) (5 questions: 1 by each member of the committee; student must answer 4 questions) 2. Oral examination (presentation of the student's thesis proposal followed by questions and discussion of thesis proposal and written examination) must be completed by April 15 (normally in the two weeks following Spring Break) or October 15. *If not pass, CEC decides among retake, conditional pass, or terminal MS recommendation.*

Comprehensive Examination for Students First Enrolled <u>in and after</u> Fall 2026

The Comprehensive Examination consists of two steps that pursue two independent goals:

<u>Goal #1</u>: To ensure that PhD students possess the breadth and depth in fundamental knowledge that are necessary to carry out the proposed research in a meaningful way.

<u>Goal #2</u>: To ensure that PhD students possess the technical, methodological, and analytical skills that are required to successfully carry out a research project and disseminate the results in a timely manner.

As a result, the Comprehensive Exam consists of two independent parts:

(1) A *General Qualifying Exam* that evaluates the student's fundamental knowledge in the chosen field of study and adjacent disciplines. This written exam is tailored to assess the student's ability to meet Goal #1.
(2) A *PhD Proposal Defense* that assesses the student's ability to conduct independent research. This exam is designed to determine the student's progress toward meeting Goal #2.

Each student must select a permanent thesis advisor and major field of study prior to the end of his/her first semester. The student will be provided with academic guidelines for the chosen major field of study. The guidelines will include a recommended sequence of courses and a summary list of Essential Knowledge for the major field of study. The Essential Knowledge Lists (EKL) for major EAS disciplines are provided in the Appendix.

The General Qualifying Exam Committee (GQC) will consist of the student's permanent advisor, two academic faculty members chosen by the student from the student's Thesis Advisory Committee (TAC), and two academic faculty members appointed by the Graduate Studies Committee (GSC). One of the GSC appointed members will be the committee chair and the other from a research area outside the student's area.

<u>*General Qualifying Exam*</u>. The *General Qualifying Exam* must be taken by the student no later than 18 months after commencing their PhD studies in EAS. For instance, a student who joined the PhD program on 15 August 2026 will need to complete this exam no later than 15 February 2028. The exam can be taken at any point in time before this deadline. The optimal timing should be discussed and agreed upon by the student and their advisor.

Students can petition the EAS graduate studies committee to postpone the *General Qualifying Exam* until the end of the semester during which they reach the 18-month deadline. In the example above, this would result in an extension of the deadline to 15 May 2028. This petition must be submitted in writing to the chair of the EAS GSC, accompanied by a brief statement of support from the thesis advisor and a description of the reasons for the requested extension. A common reason for requesting an extension is that the student is taking a class during that semester which provides knowledge immediately relevant to the exam. In such a case, the student will be allowed to complete that class before taking the exam.

The student and their advisor determine an appropriate date/time frame for the exam. At least five months before the exam, the student needs to submit the *EAS PhD Qualifying Exam Registration Form* to the chair of the EAS GSC. This form shall include the names of two EAS academic faculty members (other than the advisor) who are familiar with the student's field of study and have agreed to serve on the exam committee. The advisor and these two faculty members will also form the student's *Thesis Advisory Committee (TAC)* that guides them throughout their studies. In this form, the student shall provide their chosen mode for the exam: (i) either an eight-hour written exam (closed notes, closed books), or (ii) a 2.5-hour oral exam.

Within one week after receipt of this notification, the chair of the EAS GSC will assign two additional EAS academic faculty members to the student's exam committee. One of these two faculty members shall be designated as the exam committee chair. The other faculty member shall be external to the student's research discipline. For instance, the external member for a student working in geophysics could be an atmospheric chemist or a space physicist.

No later than four months before the anticipated exam date, the student, in collaboration with their advisor, shall formulate and submit their EKL to all five members of the exam committee, with a copy sent to the chair of the EAS GSC. Students may adopt one of the existing Essential Knowledge lists for major disciplines and tailor it to their field of research. Note, however, that the list needs to cover the full breadth and depth of that field and adjacent disciplines. Within three weeks upon receipt, the chair of the GQC shall inform the student if the list is acceptable as-is or needs modifications.

If the student selects the written form of the exam, each of the five GQC members shall provide a question for this exam. The contents of these questions must be covered by the student's EKL. The chair of the exam committee is responsible for ensuring that the five questions cover the full breadth and depth of the student's EKL. The student is required to answer four of these five questions.

If the student selects the oral option, the five GQC members shall convene in advance and (roughly) decide on the questions to be asked by each of them. The content of these questions must be covered by the student's EKL, and the GQC chair will ensure that the questions cover the full breadth and depth of the student's EKL. While it is understood that the questions in the actual oral exam may deviate slightly from this pre-planned list, each GQC member must make every effort to stay within the scope agreed upon with their peers before the exam.

After the exam, the GQC members will convene to determine the outcome. A meeting (in-person or virtual) of the whole committee is required for both the written and the oral option. Determining the exam outcome by email, chat, or any other means of communication is not permitted. The structure of this meeting shall adhere to the following sequence of steps:

(1) Initial deliberation among the "reduced" committee (four members) on the student's performance. The advisor is absent during this discussion.
(2) The "reduced" committee reaches a preliminary decision, which is recorded on the exam evaluation form.
(3) The advisor joins, and the other four committee members present their findings. The advisor now has an opportunity to weigh in and provide context as needed.

(4) All five committee members vote on the outcome of the exam (pass/fail). This vote must be anonymous. An absolute majority is required in support of the decision. Abstention from the vote is not permitted. There is no “conditional pass” option.
(5) The outcome of the vote and final decision are recorded. If the outcome differs from that of step #2, the reasons must be discussed and recorded.

The student will be informed (in person) by the GQC chair and/or the advisor about the outcome of these deliberations. For the “oral” option, the GQC will meet for discussion immediately after the exam and the student will be informed about the outcome right away. For the “written” option, it is the committee chair’s responsibility to ensure that the student receives a decision within five business days of the exam date. In both cases, the student evaluation will be reported in the *General Qualifying Exam Evaluation Form* and a copy provided to the student.

If (and only if) the student passes the General Qualifying Exam, they become eligible to take the *PhD Proposal Defense*, as detailed in the next section.

If the student does not pass the exam, they will be granted a single opportunity to make another attempt within six months of the original exam date (i.e., no later than two years after joining the PhD program, plus any extensions approved by the GSC). For this second attempt, the student has the right to change the originally selected exam mode (from oral to written or vice versa) or retain the mode chosen for the original exam. Beyond this, the structure of the exam again follows the procedure outlined in the above sections. If the student does not pass the second attempt, they are no longer eligible to pursue a PhD degree in the EAS department. In this case, the student is encouraged to contact the Graduate Coordinator about the possibility to transfer to the MSc program.

PhD Proposal Defense. After (and only after) a student has passed the *General Qualifying Exam*, they are eligible to schedule their *PhD Proposal Defense*. This defense can take place at any time after passing the *General Qualifying Exam*, but no later than 3 years (36 months) after joining the PhD program. For instance, a student who began their PhD studies on 15 August 2026 will need to schedule their proposal defense no later than 15 August 2029. The timing of the proposal defense should be agreed upon between the student and their advisor.

The exam committee for the Proposal Defense consists of the three members of student’s Thesis Advisory Committee (TAC). Additional committee members can be added at the student’s request, if these are expected to make unique and valuable contributions to the discussion.

At least ten business days before the date of the proposal defense, the student needs to submit the *EAS PhD Proposal Defense Form* to the GSC chair and their thesis proposal to all three TAC members. The first page of this proposal shall contain a project title and an abstract. The main part of the proposal shall deliver the following information:

(1) Scientific background, literature review, and context for the proposed research.
(2) Science questions to be addressed by the proposed research, as well as a discussion of their impact and relevance.
(3) A description of the technical approach and methodology chosen to achieve closure on these science questions.
(4) Preliminary results and discussion.
(5) Timeline for the completion of the project, including plans for submission of anticipated publications.

The thesis proposal will be evaluated on the basis of its scientific quality, thoroughness, and clarity. Scientific discussions with faculty members during the development of the thesis proposal are permitted and strongly encouraged. This discussion includes reference material suggestions and general outline development. Although faculty may provide feedback to students regarding their research results, the thesis proposal must be the work of the student and *faculty members are not permitted to directly contribute to the creation or editing of the thesis proposal document*. However, the student is permitted and strongly encouraged to obtain input from other students regarding matters of clarity, style and grammar. Citation of source materials is mandatory, and plagiarism will result in failure of the examination.

The thesis proposal needs to strictly adhere to the following formatting guidelines:

The manuscript body (abstract, text and figures) is limited to 35 pages; longer documents will not be accepted for review by the TAC. The text must be double-spaced with a minimum font size of 12 point and 1-inch margins. Each proposal must include an abstract and a table of contents. Figures (with captions) shall be placed in sequence at the end of the proposal and references should be formatted using either American Meteorological Society or American Geophysical Union journal specifications. The reference list is the only part of the proposal that is not included in the page limit.

The duration of the proposal defense is 90 minutes. It consists of a 30-minute public presentation by the student on the contents of their research proposal with questions from the audience, followed by a 60-minute closed Q&A session with the TAC. During this session, the TAC members will question the student on the validity and robustness of their approach, details of the chosen methodology, connections to relevant findings from the peer-reviewed literature, and mitigation strategies for possible problems encountered.

Immediately after the Proposal Defense, the student will be excused, and the TAC will determine the outcome of the defense. The decision must be supported by an absolute majority of committee members; abstention from voting is not permitted. The student will be notified immediately of the outcome. The following decisions are possible:

- <u>*Unconditional Pass:*</u> No major weaknesses in the student's research performance and progress were identified by the committee. The student is eligible to advance to PhD candidacy and must submit the *Request for Admission to Ph.D. Candidacy Form*.
- <u>*Conditional Pass:*</u> The committee has identified some minor/moderate areas of concern but believes that these issues can readily be addressed within six months of the exam date. The student needs to address these concerns and meet with the TAC again within six months to demonstrate their progress on the specific issues identified. The format and length of this meeting are determined by the TAC, but it should be significantly shorter than the original proposal defense. After all requirements of a *Conditional* Pass have been satisfied, the student is eligible to advance to PhD candidacy and must submit the *Request for Admission to Ph.D. Candidacy Form*. The decision on whether the requirements of a *Conditional Pass* have been met cannot be deferred to a subset of committee members.
- <u>*Retake:*</u> The committee has identified severe deficits in the student's research performance but still considers these to be rectifiable within six months of the exam date. The student will need to retake the Proposal Defense within six months of the original exam date. The format of this second attempt again follows the procedure outlined above. If the student passes the second attempt, they are eligible to advance to PhD candidacy and must submit the *Request for Admission to Ph.D. Candidacy Form*. If the student does not pass the second attempt, they are no longer eligible to pursue a PhD degree in the EAS department.

- <u>*Fail:*</u> The committee has identified severe and extensive deficits in the student's research performance and believes that these issues cannot be addressed within six months following the exam date. In this case, the student is no longer eligible to pursue a PhD degree in the EAS department. The student is encouraged to contact the graduate coordinator about the possibility to transfer to the MSc program.

In all cases the student shall receive the *Proposal Defense Evaluation Form* which documents the findings and recommendations of the TAC.

Timeline Associated with Comprehensive Examination

Schedule	
Fall, First year	Student chooses a permanent academic advisor and the major field of study by the end of Fall Semester. *Student selects the major field of their Ph.D. research.* *Depending on the selected field, students are provided with guidelines regarding the recommended sequence of courses (including required course on Scientific Writing) and Essential Knowledge Lists (developed for each major discipline).*
Within 18 months in the Ph.D. program <u>and</u> 5 months before the exam*	<u>General Qualifying Exam</u> Student, in agreement with their advisor, requests to take the General Qualifying Examination by submitting the *EAS PhD Qualifying Exam Registration Form* to the GSC chair. In this form: Student provides the names of two faculty members who will be part of the Thesis Advisory Committee (TAC) Student also indicates the mode of the exam chosen (either written or oral) GQC is formed by the GSC chair (TAC + two faculty members) within a week after submission of TAC names * Student can petition the GSC to delay the General Qualifying Exam to the end of the semester (~ 3 months) for extenuating circumstances
Within 4 months before the exam	Student submits their Essential Knowledge List to the GQC
Within 3 weeks from EKL submission	Student obtains summary feedback from GQC Chair.
General Qualifying Exam structure	Written examination (8 hour-long): (5 questions: 1 by each member of the GQC; student must answer 4 questions). Decision provided by the GQC chair within 5 business days Oral examination (2.5 hour-long) (questions should be decided by the GQC ahead of time and should cover the full breadth and depth of the EKL). Decision provided by the GQC on the same day. *If pass, the student is eligible to take the PhD Proposal Exam. If not pass, the student is eligible to make another attempt within six months of the original exam date. For this second attempt, the student has the right to change the exam mode.*

	If the student does not pass the second attempt, they are no longer eligible to pursue a PhD degree in EAS. In this case, the student is encouraged to contact the graduate coordinator about the possibility of transferring to the MSc program.
Anytime after passing the General Qualifying Exam, but no later than 3 years (36 months) after joining the PhD program	<u>PhD Proposal Defense</u> Student submits the *EAS PhD Proposal Defense Form* to the GSC chair, schedules the PhD Proposal Defense date, and provides an electronic copy of their proposal to the three TAC members within 10 business days of the defense The exam committee for the proposal defense consists of the three TAC members. Additional committee members can be added at the student's request. The duration of the proposal defense is 90 minutes, consisting of a 30-minute oral presentation, followed by a 60-minute Q&A session with TAC. Decision (unconditional pass, conditional pass, retake, or fail) is provided immediately after the proposal defense. *If unconditional pass, the student is eligible to advance to the PhD candidacy. If conditional pass, the student needs to address the concerns and meet with TAC again within six months of the exam date to demonstrate their progress. After all requirements of a conditional pass have been satisfied, the student is eligible to advance to PhD candidacy. If retake, the student needs to retake the Proposal Defense, following the same procedure, within six months of the original exam date. If the student passes the second attempt, they are eligible to advance to PhD candidacy.* *If fail, the student is no longer eligible to pursue a PhD degree in EAS. The student is encouraged to contact the graduate coordinator about the possibility of transferring to the MSc program.*

Admission to Candidacy

After completing all EAS course requirements and passing the comprehensive examination a student is then admitted to candidacy. For admission to candidacy the student must file with the Graduate Coordinator and the Office of Graduate Studies and Research the *Request for Admission to Ph.D. Candidacy Form*.

Annual Thesis Advisory Committee Meetings

After passing the comprehensive examination, Ph.D. Candidates must meet annually with the Thesis Advisory Committee (TAC) for an hour-long informal presentation and discussion of the overall research objectives, progress, and timeline towards graduation. The main objective of these meetings is to keep TAC informed of the research progress, provide updates on the status of publications, and gather ideas from the committee on some aspects of the research. These annual meetings will ensure the entire committee agrees with the Candidate on the science contained in the dissertation and expectations toward graduation.

Minimum Publication Requirement Before Graduation

This requirement establishes the minimum number of publications each student in the School of Earth and Atmospheric Science must submit before defending their PhD thesis. Advisers retain the right to amend this requirement by increasing the total number.

One first author publication with at least one round of reviews received and not rejected AND A second first author publication ready for submission

Minimum Presentation Requirement Before Graduation

This requirement establishes the minimum number of presentations each student in the School of Earth and Atmospheric Science must give on their own graduate work before defending their PhD thesis. Advisers retain the right to amend this requirement by increasing the total number.

One oral AND one poster presentation (or two oral presentations) of his/her graduate work.

The Georgia Tech Graduate Research and Innovation Conference, the Graduate Student Symposium (GSS) and any of the established departmental seminar series are valuable avenues. At least one presentation should be at a professional society conference. Presentations in front of peer graduate students or within a course do not count towards the minimum requirement.

Procedures for Dissertation Submission and Defense Scheduling

A student who is ready to schedule their dissertation defense should submit their dissertation to the Thesis Advisory Committee (TAC) at least two weeks prior to scheduling their dissertation defense. At the same time, the student should submit the *Presentation and Publication Status Form* to the Graduate Coordinator that attests to the status of their presentations as well as all published, in review, or in progress first-author publications. The citation of each published paper in this form should be accompanied by a Digital Object Identifier (DOI), whereas manuscript under revisions or submitted should be accompanied by a copy of the most recent round of reviews or a journal submission confirmation. If the above presentation and publication requirements cannot be satisfied, the student must submit a request for exemption from the requirements to the Thesis Advisory Committee, detailing the extenuating circumstances supporting the request. TAC will deliberate the request and vote anonymously under the supervision of the Graduate coordinator to decide whether the student is allowed to defend their dissertation.

The Doctoral Examination (Thesis Defense)

After the Thesis Advisory Committee finds the dissertation satisfactory, it schedules the candidate for an oral examination (Thesis Defense). The Final Doctoral Examination Committee, as approved by the Office of Graduate Studies and Research, will conduct the examination. The location, title of thesis, abstract of the work, and members of the Final Doctoral Examination Committee must be submitted to the Office of Graduate Studies at least 15 working days prior to the defense. A short biosketch of the external committee member(s) should be submitted to the Graduate Coordinator for their records.

The Thesis Defense consists of a seminar-style public presentation by the candidate, followed by questions from the public, and a closed session with the Doctoral Examination Committee to answer more questions related to the student's Ph.D. research. The Doctoral Examination Committee will deliberate in private, provide suggestions for eventual changes of the Ph.D. Thesis, and vote to approve the Ph.D. thesis. Once the final Ph.D. thesis is approved, the candidate submits the thesis along with the *Certificate of Thesis Approval* to the Graduate School by the appropriate deadline.

IV. Official Institute Forms and Committees

Ph. D. Students

Request for Admission to Candidacy

This form must be completed for admission to candidacy. The student's General Qualifying Exam Committee, Graduate Coordinator or School Chair, and the Graduate Studies Office must approve the form.

Petition for Degree (Online Application for Graduation)

This form must be submitted early in the semester prior to the one in which the student expects to graduate (https://registrar.gatech.edu/info/online-application-graduation-oag-graduate-students).

Thesis Advisory Committee

The Thesis Advisory Committee consists of at least three members, one of whom is the Thesis Advisor. This Committee should be formed during the second semester of residence, as it may help in part to guide the preparation of the Thesis Proposal as well as thesis research. The Thesis Advisory Committee signs the "Request for Admission to Candidacy" form and submits it to the Graduate Office. The Thesis Advisory Committee provides advice and guidance during the research and is charged with approving the dissertation when the research is completed and presented as the doctoral dissertation. When the Thesis Advisory Committee considers the dissertation to be satisfactory, a recommendation is made to the Dean of the Graduate Division for the appointment of the second committee, which is called the Final Doctoral Examination Committee.

Final Doctoral Examination Committee

The Final Doctoral Examination Committee consists of at least five members, always including the Thesis Advisory Committee members and others, as appropriate, who are recommended by the School to the Dean of the Graduate Division for approval. At least one member of the Final Doctoral Examination Committee must be from a School or College other than the unit in which the student is enrolled. The School of Earth and Atmospheric Sciences strongly recommends that at least one member of the Final Doctoral Examination Committee be from a university or research establishment other than Georgia Tech.

It is permissible to appoint a Thesis Advisory Committee which consists of five or more members and to recommend this committee to serve as the Final Doctoral Examination Committee, provided the above constraints are met for both Committees.

M.S. Students

Approved Program of Study

The *Program of Study Form* lists the courses the student proposes to use to satisfy the M.S. degree requirements. It should be completed by the second semester of the program, approved by the Graduate Coordinator and submitted to the Registrar. This form must be submitted before or simultaneously with the **Petition for Degree** form.

Petition for Degree (Online Application for Graduation)

This form must be submitted early in the semester prior to the one in which the student expects to graduate (https://registrar.gatech.edu/info/online-application-graduation-oag-graduate-students).

Request for Approval of Thesis Topic

This form should be completed once reasonable progress has been made on thesis research. The form must be approved by the student's *Thesis Reading Committee* and School Chair.

Thesis Reading Committee

The Thesis Reading Committee consists of at least three members, one of whom is the Thesis Advisor. The majority of Committee members must be members of the Academic Faculty. The Thesis Reading Committee is formed as soon as possible after the student initiates their thesis research. The Thesis Reading Committee provides advice and guidance during the research and is charged with approving the thesis when the research is completed and presented in partial fulfillment for the Master's degree. When the Thesis Reading Committee considers the thesis to be satisfactory, the candidate submit the final version along with the *Certificate of Thesis Approval* to the Graduate School by the appropriate deadline.

V. Additional Information

Additional information regarding guidelines and procedures of the School and Institute can be obtained from the Graduate Coordinator's office or the Office of Graduate Studies. These include:

(1) The Comprehensive Exam
(2) The Georgia Tech General Catalog
(3) Georgia Tech's Guidelines for Ph.D. Dissertation Research
(4) Manual for Graduate Theses

VI. Appendices

Ph.D. Milestone Checklist

M.S. Milestone Checklist

Advisor Form

Advisor Registration Form -- *Advisor* approval of Course Schedule for each semester; present to the *Graduate Coordinator* for removal of School Registration Hold

Policy on Hour Loads for Graduate Students (Credit Hours)

Essential Knowledge Lists for Major EAS Disciplines (for the PhD General Qualifying Examination)

Graduate Student Annual Report

Note required Institute forms can be found at:
http://www.grad.gatech.edu/theses-dissertations-forms

Ph.D. MILESTONE CHECKLIST

Milestone Activity	Target Completion Time	Date Completed
Select Permanent Thesis Advisor:	Prior to end of first semester	
Select major field of study:	Prior to end of first semester	
Complete online CITI RCR course:	Prior to end of first semester	
Take EAS 6000 (Prof. Preparation):	Prior to end of first semester	
Select TAC[1], register for the General Qualifying Exam, and choose the exam format (written or oral):	Five months before the exam	
GSC chair formulates GQC[2]:	Within a week after registration	
Construct tailored EKL[4]:	Four months before the exam	
Obtain approval of EKL from GQC:	Within three weeks of submission	
Submit plans for Academic Breadth and Minor Course Requirements to EAS graduate coordinator:	Prior to taking the comp exam	
GSAR[3]: Annual progress evaluation:	Annually: prior to April 15	
Take PhD Qualifying Exam	Five months after registration	
Register for the PhD Proposal Thesis Defense and submit thesis proposal to TAC:	After passing the Qualifying exam, within 36 months in PhD program	
Take PhD Thesis Proposal Defense:	Ten days after proposal submission	
Submit/present paper at national/ international scientific meeting:	Prior to end of second year	
Submit Admission to Candidacy:	After comprehensive exam	
Annual meeting with Thesis Advisory Committee to discuss research progress:	Annually after year 2	
Submit first-authored paper for publication in peer-reviewed scientific journal:	Prior to end of third year	
Complete PhD Minor/Submit Form:	Prior to end of 6th semester	
Write Thesis (Obtain Manual of Graduate Theses from Office of Graduate Studies):	During fifth year in residence	

Have 2nd first-authored paper ready for submission in peer-reviewed scientific journal: One semester prior to graduation ____________

Complete Degree Petition (OAG[5]): One semester prior to graduation ____________

Formulate Final Doctoral Examination Committee for Ph.D. defense: One semester prior to graduation ____________

Submit the Presentation and Publication Status Form to the Graduate Coordinator: At least 14 days prior to thesis defense ____________

Notify Office of Graduate Studies of scheduled thesis defense, including date, time, location, thesis title, and members of Final Doctoral Examination Committee (Thesis Advisor/Graduate Coordinator): At least 14 days prior to thesis defense ____________

Distribute thesis to Final Doctoral Examination Committee: At least 14 days prior to thesis defense ____________

Defend thesis Prior to end of fifth year in residence ____________

Submit final version of thesis plus required forms to Graduate Thesis Office

Deadlines vary: Check GT Calendar ____________

[1]Thesis Advisory Committee (Advisor + 2 members chosen by the student)

[2]General Qualifying Examination Committee (Thesis Advisory Committee + 2 members chosen by EAS Graduate Studies Committee)

[3]Graduate Student Annual Report

[4]Essential Knowledge List (for comprehensive examination)

[5]Online Application for Graduation

M.S. MILESTONE CHECKLIST

Milestone Activity	Target Completion Time	Date Completed
Select Thesis Advisor:	Prior to end of first semester	___________________
Select MS Program of Study:	Prior to end of first semester	___________________
Complete online CITI RCR course:	Prior to end of first semester	___________________
Select Thesis Reading Committee:	Prior to end of second semester	___________________
GSAR[1]: Annual progress evaluation:	Annually: prior to April 15th	___________________
Approval of MS thesis topic:	Prior to end of third semester	___________________
Complete Degree Petition (OAG[2]):	One semester prior to graduation	___________________
Write Thesis (Obtain Manual of Graduate Theses from Office of Graduate Studies):	During second year in residence	___________________
Distribute thesis to Thesis Reading Committee:	1 month prior to thesis submission	___________________
Complete Certificate of Thesis Approval (signed by Thesis Reading Committee and Graduate Coordinator):	1 week prior to thesis submission	___________________
Submit final version of thesis plus required forms to Graduate Thesis Office	Deadlines vary: Check GT Calendar	___________________

[1]Graduate Student Annual Report

[2]Online Application for Graduation

COURSE CHECKLIST FOR NON-THESIS MS
(minimum of 21 letter grade hours)

EAS 6000+ graded, 12 hrs: ________ ________ ________ ________

Elective 4000+, 6 hrs: ________ ________

Elective 6000+, 9 hrs ________ ________ ________

Spec Prob 8901, 3 hrs ________

TOTAL, 30 hrs ________

COURSES CHECKLIST FOR MS WITH THESIS
(minimum of 18 letter grade hours)

EAS 6000+ graded, 12 hrs: ________ ________ ________ ________

Elective 4000+, 6 hrs: ________ ________

Undesignated, 6 hrs ________ ________

EAS 7000, 6 hrs ________

TOTAL, 30 hrs ________

SCHOOL OF EARTH AND ATMOSPHERIC SCIENCES

Permanent Advisor Form (Due at the end of 1st semester)

Student Name: ________________________________

Major Field of Study: ___________________________

Advisor Name: ________________________________

I agree to serve as the *Permanent Advisor* for the above student.

Advisor's Signature: ____________________________ Date: ________________

Advisor will support: Yes ________ No _______ *Advisor's* Initials _______

Comments:

EAS Registration Form

SCHEDULE: ___________________ **SEMESTER, 20**____________

Are you taking the Comprehensive Examination this term? Y/N
If "yes" sign up for EAS 7999 (P/F)

STUDENT NAME: ________________________ STUDENT NUMBER: _____________

COURSE	MEETING TIME	BASIS	CREDIT HOURS
________________	_______________	______	________________
________________	_______________	______	________________
________________	_______________	______	________________
________________	_______________	______	________________
________________	_______________	______	________________
________________	_______________	______	________________
________________	_______________	______	________________
________________	_______________	______	________________
________________	_______________	______	________________

Total (LG + P/F)* =_______________

* Must be at least 12 hours to maintain classification as full-time student.

For EAS 7999A (Comp. Exam) and/or any Special Problems courses which must be approved by instructor:

COURSE	INSTRUCTOR	INSTRUCTOR'S SIGNATURE
________	______________	___________________________
________	______________	___________________________
________	______________	___________________________

Approval: _______________________ Date: __________________

Faculty Advisor

_______________________ Date: __________________

Graduate Coordinator

Policy on Hour Loads for Graduate Students

The complete text of the Institute's policy on hour loads can be found at: http://www.policylibrary.gatech.edu/employment/hour-loads-graduate-students. EAS graduate students and their advisors will generally be able to follow the abbreviated procedures outlined below.

Full-time Students

Graduate students holding appointments as graduate research assistants (GRA's) or as graduate teaching assistants (GTA's) must be full-time students. Full-time graduate students should be enrolled for 18 or more (maximum of 21) credit hours in the Fall and Spring semesters and for a maximum of 16 credit hours in the Summer term. **At least 12 credit hours must be taken on a letter grade or pass/fail basis.** Many possible combinations of scheduled courses, seminars, and research can be used to meet these credit hour requirements. Only courses taken on a letter grade or pass/fail basis can be used to meet Institute requirements for full-time status.

EAS graduate students are allowed to take 4000-level courses. If 4000-level courses are taken on a letter grade or pass/fail basis and have not been used previously to meet the requirements for another degree, those courses can also be used to partially satisfy Institute requirements for undesignated or designated M.S. degrees. With the approval of the EAS Graduate Coordinator and the Institute, 4000-level courses may be included in the nine semester hours constituting a student's academic minor.

All 6000-level EAS courses, when taken on a letter grade or pass/fail basis, can be used to meet Institute requirements for full-time status. Those courses can also be used to satisfy Institute requirements for the undesignated or designated M.S. degree.

The following courses at the 7000-9000 level are often used to partially satisfy requirements for a degree or for full-time status. Each of these courses is in some respects limited, so care must be exercised when using them to meet requirements for hour loads.

EAS 7000 – This course is taken on a pass/fail basis by students studying for the *designated* M. S. degree. These students are expected to devote an appropriate amount of time to thesis research under the supervision of a thesis advisor. It is the principal means by which these EAS students adjust their overall course load to meet the Institute's requirements for full-time enrollment.

EAS 7999 – This course is taken by doctoral students in the term in which they take the comprehensive examination. The course is taken on an audit basis and thus does not count toward the minimum requirement of 12 hours on a letter grade or pass/fail basis.

EAS 8001 – This course is a research seminar, and it can be taken as often as desired on a pass-fail basis. It counts toward the minimum requirement of 12 hours on a letter grade or pass-fail basis. Students seeking the designated M. S. degree can use up to three credit hours of EAS 8001 toward the M. S. degree.

EAS 8011 – This course is the EAS School seminar. Pre-candidacy doctoral students and thesis-based M.S. students are required to take it every semester on a pass/fail basis, whereas post-candidate doctoral students and undesignated M.S. students are strongly encouraged to take it every semester on a pass/fail basis. It counts toward the minimum requirement of 12 hours on a letter grade or pass/fail basis.

EAS 880x (x=1-6) – These are "Special Topics" courses for 1-6 credit hours. This designation will be used for a lecture-only course that is not already an officially approved course in the Institute catalog. Such courses should be taken for a letter grade.

EAS 882x (x=3-5) – These are "Special Topics with a Laboratory" courses for 3-5 credit hours. This designation will be used for a lecture-plus-laboratory course that is not already an officially approved course in the Institute catalog. Such courses should be taken for a letter grade.

EAS 890x (x=1-4) – These are "Special Problems" courses and the credit hours are variable from course to course and from term to term. This designation will be used for less structured intellectual activities that require supervision by a faculty member. For example, students studying for the *undesignated* M. S. degree are required to complete a three-hour Special Problems course. Activities that might be appropriate in a Special Problems course include literature research, laboratory research, computational projects, etc. Such courses should be taken for a letter grade

EAS 8997 – This course can be taken by students who are appointed as graduate teaching assistants in EAS. It can only be taken on an audit basis (recommendation of 1 credit hour) and thus does not count toward the minimum requirement of 12 hours on a letter grade or pass/fail basis.

EAS 8998 – This course can be taken by students who are appointed as graduate research assistants in EAS. It can only be taken on an audit basis (recommendation of 1 credit hour) and thus does not count toward the minimum requirement of 12 hours on a letter grade or pass/fail basis.

EAS 9000 – This course is taken on a pass/fail basis by students studying for the Ph.D. degree. Those students are expected to devote an appropriate amount of time to thesis research under the supervision of a thesis advisor. It is the principal means by which those students adjust their overall course load to meet the Institute's requirements for full-time enrollment.

Full-time students working exclusively on thesis research should be registered for 18 or more hours of 7000 or 9000 (Master's or Doctoral Thesis) in Fall and Spring semesters, and for up to 16 hours during Summer semesters.

A student may register for only one hour of Master's or Doctoral Thesis (7000 or 9000) during the semester of graduation. This exception may be used once for each degree.

Part-time Students (Reduced Course Load Options)

Graduate students can be enrolled part-time only if they plan on not being enrolled at Georgia Tech for the entire semester and do not take courses. These students should register for either 1 or 3 credit hours under a Reduced Course Load. Students registered under a Reduced Course Load are financially responsible for paying any tuition, mandatory fees, etc. during that semester. Students under a Reduced Course Load will also not receive a GTA or GRA stipend. However, students may apply for a Temporary Staff (Tech Temp) position with their advisor, providing funding is available.

Three Hour Rule

The minimum load for part-time students is 3 credit hours, but students should be encouraged to take the maximum load they can handle in order to progress toward completion of the degree.

One Credit Hour Rule

A student may register for only one hour of Master's or Doctoral Thesis (7000 or 9000) during the semester of graduation. This exception may be used **only once per degree**. No special form or permission is needed if the student is a degree candidate (https://policylibrary.gatech.edu/employment/hour-loads-graduate-students**)**.

Students who have enrolled for one hour only more than one time per degree are not eligible to take advantage of the waiver of enrollment. They must enroll for the normal minimum of three hours in the semester of graduation. These exceptions **do not** alter the credit-hour load a student must take to meet financial aid, fellowship or assistantship eligibility, etc. Students on F-1 visas should speak with the Office of International Education (OIE) before adopting a reduced course load or not enrolling. Students intending to enroll in the Student Health Insurance Plan must be enrolled in a minimum of four credit hours to participate in the plan.
Students should **address any questions or concerns** regarding enrollment during the last semester **to the Graduate Education Thesis Office before the end of registration**; no additions or changes in registration are allowed after the close of registration.

Waiver of Enrollment

The requirement that a graduate student be enrolled during the semester of graduation may be waived if the student is no longer using Institute or faculty time during the semester of graduation **AND**:

1. the student was duly registered the previous term (usually the term in which the successful final defense took place); and

2. the final and complete electronic thesis is submitted, all thesis-related forms are received by the Graduate Education Thesis Office, and all other graduation-related requirements are satisfied before the end of the registration period the semester of graduation.

The intent is that a student who has been properly registered during the period of thesis completion and who has completed all work at Georgia Tech and therefore has nothing to register for should not be required to enroll another term to graduate. The Enrollment Waiver is available from the "Forms" menu at the Graduate Education Thesis Office website (http://www.grad.gatech.edu/theses-dissertations-forms**).** The Waiver of Enrollment ("Enrollment Waiver") form signed by the student and his or her department should be turned into the Graduate Education Thesis Office at the same time as the Certificate of Thesis Approval Form.

The waiver of enrollment **does not** waive the requirement that the student file or reactivate a degree petition (Online Application for Graduation) by the deadline for the term in which the degree is to be awarded. There are no exceptions to the enrollment waiver deadline for thesis students. Students must meet the deadline or register as required.

Guidelines for Registration of Doctoral Dissertation Hours (EAS 9000)

a. Beginning full-time doctoral students, especially those who are research assistants, are encouraged to register for at least 3 hours of 9000. This allows and encourages students to maintain a lighter academic load to begin laying the groundwork for Ph.D. research.

b. Advanced full-time doctoral students who are working primarily on their dissertation research should register for 18 or more (maximum of 21) hours of 9000 in Fall and Spring semesters, and for up to 16 hours of 9000 for Summer semesters. If they are taking other coursework, this has to be approved by the Advisor and the number of 9000 hours is reduced by the number of formal coursework hours. The Advisor and/or Graduate Coordinator determines whether the total is above 18 for Fall and Spring semesters.

c. Part-time doctoral students engaged in the research phase of the Ph.D. should register for 9000 consistent with their and their faculty member's activity on the dissertation research.

d. All full-time students coded as Master's students but involved in preparation for the Ph.D. are encouraged to register for 9000 consistent with the amount of work involved.

Essential Knowledge Lists for Major EAS Disciplines

Essential Knowledge List for Atmospheric and Climate Dynamics students

This document serves as a summary of the background knowledge and skills that are expected of PhD level students studying atmospheric and climate dynamics at Georgia Tech. The information listed here is primarily covered in a series of "core" atmospheric science courses, advanced specialty courses, disciplinary seminar series, and individual research endeavors. Undergraduate technical training in chemistry, mathematics (up to vector calculus and ordinary differential equations) and calculus-based physics is assumed and is not explicitly covered in the core atmospheric science courses. The graduate-level core courses include Introductory Fluid Dynamics and Synoptic Meteorology, Introduction to Climate Change, Thermodynamics of Atmospheres and Oceans, and Environmental Data Analysis. Although these courses are not requirements per se, they are first-year graduate courses that most students will take.

Descriptive Knowledge of the Atmosphere and Climate

- Atmospheric composition and global vertical structure
- General circulation characteristics and seasonal variability
- Principal atmospheric scales and periodicities
- Extratropical weather systems: Air masses, fronts, cyclones, teleconnections and weather regimes
- Tropical weather systems: Tropical storms, monsoons, El Niño-Southern Oscillation, Intraseasonal Oscillation
- Atmospheric boundary layer
- Current and past climate characteristics
- Role of the atmosphere in the Earth System
- The atmospheric hydrologic and carbon cycles

Atmospheric Fluid Properties, Statics, and Kinematics

- Continuum hypothesis, ideal gas, equation of state
- Hydrostatic balance, pressure as a vertical coordinate, geopotential
- trajectories and streamlines, horizontal divergence and deformation, circulation and vorticity
- Nondivergent and irrotational flows, streamfunction and velocity potential
- Total derivative, material conservation principle and spatial advection
- Lagrangian and Eulerian characterizations of fluid time evolution

Thermodynamics of the Atmosphere and Ocean

- First Law of Thermodynamics, adiabatic processes in the atmosphere and ocean
- Entropy, Second Law of Thermodynamics, transport and time dependency
- Moist thermodynamic processes, static stability, buoyancy and convection
- Cloud and precipitation microphysics, cloud characteristics and radiative properties
- Surface exchange of heat and moisture, energy and salinity budget, ocean mixed layer

Fundamental Conservation Laws and Equations of Motion

- Conservation of mass: Continuity equation
- Conservation of energy: Thermodynamic equation
- Conservation of momentum: Navier-Stokes equations
- Inertial and noninertial reference frames
- Conservation of angular momentum and spherical coordinates
- Rotating reference frame, Centrifugal force, Coriolis force, effective gravity
- Primitive equations (rotating spherical reference frame)

Fundamental Approximations and Large-Scale Balanced Circulations

- Rossby number and scale analysis of the primitive equations

- Geostrophic approximation and the thermal wind equation
- Inertial, geostrophic, gradient and cyclostrophic circulations
- Quasi-geostrophic approximation and diagnostic application
- Circulation theorem, Vorticity and potential vorticity equations
- Large-scale dynamical balance for the tropical atmosphere

Atmospheric Waves and Instability
- Linear theory, perturbation methods and wave properties
- Acoustic, gravity, and Rossby waves,
- Equatorial wave theory: Rossby-gravity and Kelvin waves
- Baroclinic, barotropic, inertial and convective instability

Global Energy Cycle and Global Climate
- Global energy balance and the greenhouse effect
- Solar and infrared radiative transfer in the atmosphere
- Radiative-convective equilibrium and role of clouds
- Regional energy balance and poleward energy transport
- Surface energy balance and the atmospheric boundary layer
- Roles of hydrologic cycle and oceanic circulation in climate

General Circulation and Climate Variability
- Zonally averaged circulation and angular momentum budget
- Longitudinally varying seasonal mean circulation (stationary waves)
- Lorenz energy cycle and the role of large-scale Rossby waves
- Coupled climate variability (land surface, biosphere, cryosphere, thermohaline circulations, El Nino)
- External natural climate forcing (orbital and solar variability, volcanic eruptions)
- Anthropogenic influences (greenhouse gases, tropospheric & stratospheric ozone, sulfate aerosols)
- Climate feedback processes, climate sensitivity, and climate equilibria
- Numerical simulation and prediction of climate variability

Basic Computing and Mathematical Skills
- Needs will vary: Suitable combination of Matlab, IDL, Fortran, GrADS, Ferret, or similar
- Basic Unix/Linux, Unix shell scripting, operating on multi-dimensional datasets (e.g., netCDF, GRIB)
- Vector calculus operations, matrix & vector algebra, Taylor series, linear differential equation solutions
- Basic statistical inferences, data fitting and least square theory, time series analysis, regression analysis
- Spectral analysis, orthonormal functions, Fourier series, principle component analysis, wavelet analysis
- Numerical methods, discretization schemes, error and stability analysis, nonlinear systems, inverse methods

Specialized Skill Sets
- Mesoscale circulations: fronts and frontogenesis, symmetric instability, topographic waves, convective storms
- Tropical dynamics: Scale analysis, equatorial wave theory, steady forced motions, tropical cyclone physics
- Stratosphere: Ozone hole, stratospheric warmings, Brewer-Dobson circulation, annular modes, QBO

Key Textbook Resources
- An Introduction to Dynamic Meteorology, James R. Holton, Elsevier/Academic Press
- Global Physical Climatology, Dennis L. Hartmann, Elsevier/Academic Press
- Thermodynamics of Atmospheres and Oceans, Judith Curry, Peter Webster, Elsevier/Academic Press
- Discrete Inverse and State Estimation Problems, Carl Wunsch, Cambridge Press
  Statistical Methods in the Atmospheric Sciences, Daniel Wilks, Elsevier/Academic Press

Essential Knowledge List for Atmospheric Chemistry Students

This document serves as a summary of the background knowledge that is expected of PhD level students specializing in atmospheric chemistry at Georgia Tech. The information listed here as essential knowledge for all students is covered in four graduate courses: Atmospheric Chemistry, Thermodynamics of Atmospheres and Oceans, Atmospheric Aerosols, and Aerosols, Clouds, and Climate. Other courses that may be useful for some students depending on their background and research focus include Biogeochemical Cycles, Air Pollution Physics and Chemistry, and Atmospheric Radiative Transfer. Undergraduate technical training in chemistry, calculus-based physics, and mathematics (up to vector calculus and ordinary differential equations) is assumed and is not explicitly covered in graduate coursework. Students with no undergraduate training in Earth System Science would benefit from a TA assignment in one of the EAS freshman-level courses. Recommended textbooks for learning or reviewing essential knowledge topics are (1) *Introduction to Atmospheric Chemistry* by D.J. Jacob, Princeton University Press, 1999, and (2) *Atmospheric Chemistry and Physics, 2nd ed.*, by J.H. Seinfeld and S.N. Pandis, John Wiley & Sons, 2006.

All atmospheric chemistry students should be familiar with the following:

Basic Components of Earth System Science

- Freshman undergraduate level of understanding

Atmospheric Transport

- Specific topics and level of understanding as covered in Ch. 4 of Jacob.

Basics of Gas Phase Kinetics

- Bimolecular and termolecular reactions
- Pseudo-first order reactions and the concept of lifetime
- Steady state approximation

Basics of Photochemistry

- Beer-Lambert law
- The concept of the j-value
- Dependence of j-values on solar zenith angle
- Correspondence between absorption spectra and j(z)

Basics of Aqueous Phase and Multi-Phase Reaction Kinetics and Equilibria

- Acid-base equilibria
- Henry's law
- Mass transport limitations
- The resistor model for multi-phase kinetics
- Level of understanding of the above topics as covered in Ch. 7 and 12 of Seinfeld and Pandis

Simple Models for Describing Atmospheric Chemical Systems

- Box and Puff models
- Level of understanding of the above topics as covered in Ch. 3 of Jacob

Atmospheric Aerosol

- Source/sink mechanisms
- Characteristic size distributions
- Basic elements of aerosol microphysics including nucleation
- Condensation/evaporation and coagulation
- Aerosol thermodynamics
- Secondary organic aerosol (SOA) formation mechanisms and partitioning
- Interaction of aerosols with radiation
- Level of understanding of the above topics as covered in Ch. 8−15 of Seinfeld and Pandis

Elementary Cloud Physics

- Basic mechanisms for cloud formation (the parcel model concept)

- Humidity variables
- Saturated adiabatic lapse rate
- Adiabatic liquid water content
- Convective cloud formation
- Köhler theory
- Level of understanding of the above topics as covered in Ch. 17 of Seinfeld and Pandis

Stratospheric Ozone Chemistry
- Chapman mechanism
- Catalytic cycles involving HO_x, NO_x, and halogen radicals
- Factors controlling efficiencies of catalytic cycles (null cycles and reservoir species)
- Antarctic ozone hole and stratospheric heterogeneous chemistry
- Sources of stratospheric pollution
- Ozone depletion potentials
- Level of understanding of the above topics as covered in Ch. 10 of Jacob

Oxidizing Capacity of the Troposphere
- Chemistry of the coupled O_3, HO_x, NO_x, CH_4 system
- Chemical regimes for net photochemical production/destruction of tropospheric O_3
- Budgets of HO_x, NO_x, CH_4, and CO
- Level of understanding of the above topics as covered in Ch. 11 of Jacob

Urban and Regional Air Quality
- NO_x– and hydrocarbon–limited regimes for O_3 production
- Role of aerosols in air quality
- Sources of primary aerosol
- Mechanisms for formation of SOA in polluted environments
- Level of understanding of the above topics as covered in Ch. 12 of Jacob

Chemistry and Climate
- The greenhouse effect
- The concept of radiative forcing
- Global warming potentials
- Stratospheric cooling by greenhouse gases
- The indirect effect of aerosol on climate
- Level of understanding of the above topics as in Ch. 7 of Jacob and Ch. 23-24 of Seinfeld and Pandis

The following material is essential knowledge for students in specific research groups

Radiative Transfer
- Rayleigh scattering
- Mie scattering
- Multiple scattering with application to aerosols and clouds
- Absorption

Trace Gas Levels, Sources, and Sinks
- Anthropogenic, biogenic, soil, and ocean emissions
- Wet and dry deposition

Atmospheric Chemical Transport Models
- Higher level of understanding than required for all students
- Level of understanding as covered in Ch. 25 of Seinfeld and Pandis

Experimental methods in laboratory studies of atmospheric processes

Experimental methods in field observations of atmospheric trace gases

Experimental methods in field observations of aerosol size and composition

Essential Knowledge List for Radiative Transfer and Remote Sensing Students

This document serves as a summary of the background knowledge that is expected of PhD level students specializing in radiative transfer processes and/or remote sensing at Georgia Tech.

- The role of atmospheric radiation in the Earth's system (energy budget, atmospheric dynamics and thermodynamics, and photochemistry).
- The nature of solar and thermal IR atmospheric radiation. Concepts of scattering, absorption, and emission. Main radiation laws. Blackbody radiation.
- Sun as an energy source. Solar spectrum and solar constant.
- Basics of gaseous absorption and emission. Concepts of a spectral line and a band. Absorption by atmospheric gases in IR, visible, and UV regions.
- Basics of interaction of electromagnetic radiation with aerosol and cloud particles. Single-scattering by spherical and non-spherical particles. The nature of light absorption by particulate matter. Lorenz-Mie theory.
- Fundamentals of the thermal IR radiative transfer. Principles of a line-by-line approach. Correlated K-distribution approximation.
- Principles of multiple scattering. Methods for solving the radiative transfer equation with multiple scattering and absorption (Two-stream and Eddington's approximations, Discrete-ordinates method, Adding method, Monte Carlo). Radiative transfer with polarization.
- Earth's energy balance. Direct and indirect radiative forcings. Radiation budget at the surface. Radiative feedbacks.
- Radiative heating and cooling rates.
- Actinic fluxes. Basics of photochemistry.
- PAR. Basics of photosynthetically active radiation and plant functioning.
- Radiation codes in regional and global atmospheric dynamical models.

Basic principles of remote sensing of atmosphere, and land and ocean surfaces.

- Principles of passive remote sensing using extinction and scattering. Scattering as a source of radiation. Multiple scattering. Applications: Sensing of ozone in the UV region. Ocean color. Sensing of clouds and aerosols (retrieval of optical depth and particle sizes)
- Principles and Applications of passive remote sensing using emission: Sensing of sea surface temperature (SST); Sensing of clouds and precipitation.
- Principles of sounding by emission. Sounding of the temperature profile. Sounding of trace gases and air pollution
- Remote sensing of radiative energy balance components (SW and LW).
- Principles of active remote sensing: Radars and lidars. Applications of radars: Sensing of clouds, precipitation, and winds. Applications of lidars: Sensing of water vapor and trace gases. Sensing of aerosols and clouds.
- Remote sensing of land surfaces. Basics of retrievals of NDVI, fPAR, surface temperature, and soil moisture.
- Applications of satellite remote sensing in weather predictions.

Recommended Textbooks:

An Introduction to Atmospheric Radiation, K.N. Liou, 2002.
A First Course in Atmospheric Radiation. G.W. Petty, 2006
Radiative Transfer in the Atmosphere and Ocean. G. E. Thomas and K. Stamnes, 1999.
Absorption and Scattering of Light by Small Particles. C. Bohren and D. Huffman, 1983.

Information on Georgia Tech Remote Sensing Certificate (https://catalog.gatech.edu/programs/graduate-embedded-certificate-remote-sensing/)

Basic Computing Skills

- Needs will vary: some combination of Matlab, IDL, and Fortran.
- Working with large datasets (e.g., HDF, netCDF)

Essential Knowledge List for Oceanography Students

This document serves as a summary of the background knowledge that is expected of PhD level students specializing in Oceanography at Georgia Tech. The information listed here as essential knowledge for all students is covered in five graduate courses: Oceanography, Ocean Dynamics, Environmental Data Analysis, Introductory Fluid Dynamics and Synoptic Meteorology and Ocean Biogeochemical Cycles. Other courses that may be useful for some students depending on their background and research focus include Thermodynamics of Atmospheres and Oceans, Ocean Modeling, Introduction to Climate Change, Turbulence in Geophysical Flows, Paleoceanography and Paleoclimate, Large Scale Atmospheric Circulation, Remote Sensing and data analysis, Climate Dynamics. Undergraduate technical training in calculus-based physics, and mathematics (up to vector calculus and ordinary differential equations) is assumed and is not explicitly covered in graduate coursework. Students with no undergraduate training in Earth System Science would benefit from a TA assignment in one of the EAS freshman-level courses.

Descriptive Knowledge of the Atmosphere and Climate

- The origin of the ocean basins, marine sediments, properties and chemistry of seawater.
- Mean and seasonal ocean circulation, waves, tides, currents, shallow water processes.
- Ocean biogeochemical cycles (e.g. carbon, nitrogen, phosphorous, oxygen cycles)
- Fundamental aspects of ocean circulation and biological productivity (coastal and open ocean).
- Physical oceanography of major current systems (e.g. gyre-scale circulations, boundary current systems and tropics).

Fundamentals of Ocean Dynamics

- Eulerian and Lagrangian kinematics.
- Equations of mass, momentum, and energy in a rotating frame of reference.
- Vorticity and divergence.
- Scaling and geostrophic approximation.
- Potential vorticity.
- Ekman layers.
- Primitive equations, equation of state for sea water.
- Barotropic and baroclinic instability.

Theory of ocean circulation

- Steady circulation in the oceans: quasi-geostrophy on the beta plane and planetary geostrophy on the sphere, Ekman pumping, wind- and thermally driven ocean circulation models, western-boundary current dynamics, and abyssal circulation.
- Wave motion in the ocean: Basic ideas of geophysical wave motion in rotating, stratified, and rotating-stratified fluids (e.g. Rossby, Kelvin, internal, gravity waves.).

Oceanography and Climate

- Global energy balance, surface energy balance, radiative transfer and climate.
- Hydrological Cycle
- Atmospheric circulation, ENSO, monsoon circulations, and fundamentals of air-sea coupling and interactions.
- Climate variability (e.g. interannual, decadal, centennial time scales), forced and intrinsic.
- The role of the ocean in climate change.

Turbulence in geophysical systems

- 3-dimensional, 2-dimensional, and quasi-geostrophic turbulence.
- Influence of stratification and rotation.
- Parameterization of turbulent processes in ocean models.

Modeling the ocean

- Numerical modeling of the ocean circulation
- Strengths and weaknesses of ocean models and different approximations
- Parameterizations

Recommended reading

Textbooks for learning or reviewing essential knowledge topics are
(1) *Open University Press: Ocean Circulation*
(2) *Atmospheric and Oceanic Fluid Dynamics* by G. Vallis, Princeton University Press, 2006,
(3) *Discrete Inverse and State Estimation Problems*, by Carl Wunsch, Cambridge Press, 2006,
(4) *Ocean Biogeochemical Dynamics*, by Jorge Sarmiento and Nicolas Gruber, Princeton University Press, 2006.

Basic Computer Skills

- Basic Unix/Linux, cluster and networked computer theory/tools
- Matlab
- Fortran (ability to function with any code)

Essential Knowledge List for Geophysical and Planetary Science Students

This document serves as a summary of the background knowledge expected of PhD students in Geophysical and Planetary Sciences at Georgia Tech. Outside of the additional knowledge identified for specific subdisciplines (denoted by **bold*** abbreviations), the information listed here will mostly be covered in a few "core courses", short courses, individual research, or can be gained through via participation in group and departmental seminars or through undergraduate studies. The graduate-level "core courses" include *Geodynamics*, *Seismology*, *Physics of Planets*, and *GeoFluids*. These courses are not meant for all but are ones most graduate students will take.

Basic Knowledge:

- Plate tectonics theory: kinematic and dynamic processes, major current plate organization
- Planetary atmospheric structure (P, T, ρ) and dominant species
- Fundamentals of heat transfer (conductive, radiative and convective)
- Major earth materials (silicate, salt, oxide mineral classes; rock types), base compositions, density and location
- 1D mechanical (G, ρ) and compositional Earth models (differentiating ocean/continental lithospheres)
- Fluid and solid mechanics: real-earth elastic and viscous moduli, stresses, flow and strain values
- Gravity: Universal law of gravity, the geoid, and structural anomalies
- Scaling, self-similarity and power-laws in nature
- Simplified phase diagrams
- Basic understanding of continuum mechanics
- Basic understanding of radioactive nuclide decay
- Electromagnetism: Basic (E/M relationship, potentials, etc.)
- Statistics and error analysis: T-,F-tests, χ^2 , random vs. systematic error
- Basic scientific paper writing and presentation skills
- Tools for geophysical exploration: seismic, remote-sensing, gravity, magnetism, geodesy, LiDAR, spectroscopy
- Earth history (planet formation, differentiation, continental growth, climatic and biotic evolution)

Math Skills

- Taylor, Fourier series
- Mathematical background: scalars, vectors, and tensor, matrix algebra, vector calculus
- Classification of differential equations (DE), homogeneous DE, linear DE and general strategies for solutions.
- Non-dimensionalized equations

Seismology

- Elastic wave propagation
- Snell's law (including Fermat's and Huygens' principles)
- Types of seismic waves, controls on velocity, important seismic phases within the Earth
- Geometric spreading, anelastic and scattering attenuation (**S**)
- Seismic anisotropy (**Gd, Gf, S**)
- Time series analysis: digital signal processing, FFT, f-domain, filtering, convolution, correlation (**Gd, S**)

Geodesy

- Okada models of slip induced deformation (**Gd, S**)
- Mogi model of spherical source deformation (**Gd**, **V**)
- Limitations of analytic vs. numerical models of deformation (**Gd**)
- Basic theory of InSAR and GPS data reduction (**Gd**)

* *Additional* knowledge necessary for: (**Gd**) Geodesy, (**Gf**) Geophysical Fluid Dynamics, (**Gm**) Geomorphology, (**P**) Planetary Sciences, (**S**) Seismology, and (**V**) Volcanology.

Earthquakes and Faults

- Elastic rebound theory
- Fault characterization using geologic, geophysical, and lab studies (**Gd, Gm, S**)
- Controlling factors for earthquake occurrence (**Gd, S**)
- Characteristics of earthquake rupture, afterslip, slow earthquakes and creep events (**Gd, S**)
- Earthquake rupture properties: directivity, length, width, slip and strength (**Gd**, S)
- Magnitude-types and calculations, seismic moment, stress drop (**Gd, S**)
- Corner frequency, and radiated energy (**S**)
- Focal mechanisms, moment tensors, Anderson's Theory of Faulting, deviations (**Gd, S**)
- Mohr-Coulomb failure, slip-weakening, Coulomb/Amonton friction, rate- and state friction (**Gd, S**)
- Omori's law of aftershock occurrence (**Gm, Gd, S**)
- Modified Mercalli Intensity scale, contributing factors in ground shaking intensity (**Gd, S**)
- Hazard assessment of earthquakes and tsunami (**Gd, S**)

Fluid Dynamics

- Conservation relationships for thermal energy, mass and momentum
- Fluid through porous media: Darcy's law
- Boundary layer analysis (**Gf, P, V**)
- Reynolds number, Stokes number, Froude number, particle flow and forces (**Gf, Gm, V**)
- Plumes, jets and gravity currents (analytic models and scaling) **(Gf, V)**
- Turbulent flows and Kolmogorov theories (and transition from laminar to turbulent flow) (**Gf, Gm, P, V**)
- Familiarity with compressible fluid dynamics (shock relations and choked flow) (**Gf, P**, **V**)
- Kinetic theory of gases (**Gf, V**)
- Basic understanding of convection/melting and source terms (radionuclides, linear melting models) (**Gf, V**)
- Fluid dynamics with interfaces (bubbles or particles) – boundary conditions (**Gf, P, V**)
- Rheology (Newtonian, Bingham, shear thinning and shear thickening) (**Gd, Gf, V**)
- Permeability structure in the crust, structural controls on permeability (**Gd, Gf, S, V**)
- Potential flows (**Gf, V**)

Volcanology and Magma Dynamics

- Mantle melting relations (wet and dry)
- Basic understanding of compositional variation in magmas (basalt – rhyolite) and their physical properties
- Volcanic system types, eruption styles and mechanisms (**Gm, V**)
- Fragmentation criteria for magma in volcanic conduits, and its relation to eruptive style (**V**)
- Fundamentals of heat transfer in crust and magmatic systems (**V**)
- Volcanic hazards **(V)**

Planetary and Rock Magnetism

- Magnetic dipole field, basic dynamo theory, magnetic reversals (field evidence)
- Curie point and magnetic susceptibility
- Space weather (sun-earth connection)
- General understanding of magnetic reconnection (**P**)
- Magnetospheric/Auroral generation and dynamics (**P**)
- Electromagnetism: Plasma, and wave dynamics (**P**)

Geomorphology and Geology

- Basic understanding of geochronologic/thermochronologic techniques

* *Additional* knowledge necessary for: (**Gd**) Geodesy, (**Gf**) Geophysical Fluid Dynamics, (**Gm**) Geomorphology, (**P**) Planetary Sciences, (**S**) Seismology, and (**V**) Volcanology.

- Feedbacks between mountain building, erosion, chemical weathering, and climate
- Fundamentals of field methods and geologic mapping (**Gd, Gm, S, V**)
- Influence of crustal structure on surface geology and topography (**Gm, S**)
- Paleoseismology and observations of faulting (**Gd, Gm, S, V**)
- Channel incision and sediment transport by rivers and debris flows (**Gf, Gm**)
- Hillslope characteristics, processes, and evolution (**Gd, Gm**)
- Hydrologic and geochemical evolution of the Earth's surface and near subsurface (**Gm**)
- Glacier dynamics and erosion (**Gd, Gm**)
- Aeolian sediment transport and landforms (**Gm**)
- Biotic influences on surface processes (**Gm**)

Planetary Science

- Planet formation
- Basic orbital and physical parameters of major solar system planetary bodies
- Characteristics of habitable planetary environments
- Two-body and restricted three-body orbits (**P**)
- Tidal forces and dissipation (**P**)
- Impact crater formation, morphology, and utility for age estimation (**P**)
- Remote sensing techniques used in planetary science – thermal inertia, gamma/X/neutron spectroscopy (**P**)

Space Plasma Physics

- 1D compositional and mechanical models of planetary bodies (**P**)
- Kinetic plasma theory, Boltzmann's and Vlasov's equations, distribution functions in space plasmas (**P**)
- Waves in plasmas: magnetohydrodynamic waves, cold plasma waves, Friedrichs diagrams, CMA diagram (**P**)
- Discontinuities in plasma fluids, Rankine-Hugoniot relations, basic physics of shocks (**P**)

Essential Knowledge List for Geochemistry Students

This document identifies the basic, or core, knowledge and skills expected from PhD candidates in geochemistry at Georgia Tech. The concepts and tools listed below represent the essential background needed to prepare for the doctoral general qualifying examinations in the field of geochemistry. The core knowledge also prepares PhD students for successful professional careers upon graduating.

Graduate students acquire the required basic knowledge and skills through course work, self-study, individual research, short courses and participation in the geochemistry seminar series. Usually, this is done during the first two years of enrollment in graduate school. Students with prior academic training at the graduate level may already have met all or part of the requirements.

The list below is divided in two parts. Part I covers the basic knowledge expected from all geochemistry students, irrespective of their specialization. Part II covers the basic knowledge for the geochemical subdisciplines represented at Georgia Tech.

Part I: General

- Basic principles and concepts of general, inorganic and organic chemistry
- Laws of thermodynamics, entropy, free energy, chemical potential, standard states, Phase Rule, Gibbs-Duhem relation, phase diagrams
- Application of equilibrium thermodynamics to geochemical systems: gases, mixtures, mineral equilibria, solid solutions, aqueous solutions
- Activity-concentration relations, Debye-Hückel equation, ion pairs, complexes
- Redox equilibria, redox potential, pe, pe-pH diagrams
- Computer-assisted thermodynamic calculations (MINTEQ, MINEQL, PHREEQ, etc.)
- Empirical rate equations, reaction mechanisms, Arrhenius equation, collision theory, transition state formulation of rate constant
- Structure of mineral-water interface, adsorption isotherms, controls on weathering and mineral formation
- Diffusion, advection, dispersion and their mathematical representations
- Conservation equations, boundary and initial conditions, analytical solutions (simple cases)
- Basic knowledge of the chemistry of natural waters, earth surface minerals and natural organic matter
- General characteristics of oceanic and atmospheric circulation
- Stable isotopes: fractionation, delta notation, Rayleigh model

Part II: Subdisciplines

1. Biogeochemistry

- General overview of the water, carbon, nitrogen, sulfur, phosphorus, silicon and iron cycles, sources and sinks of greenhouse gases
- Detailed understanding of carbonate chemistry and its role in carbon cycling
- Dynamic modeling: mass balance equations (ODEs), initial conditions, scenarios, numerical solutions, residence times, response times

2. Chemical oceanography

- General knowledge of geochemical analysis and sampling of ocean water, particulate matter and seafloor sediments
- Basic understanding of
    - physical oceanography (surface, deep and boundary circulation),
    - biological oceanography (productivity, nutrients, trophic interactions),
    - marine geology (plate tectonics, ocean basin morphology, proxies), and
    - early diagenesis (organic matter degradation, redox zonation, bioturbation, preservation)

3. Geomicrobiology

- Theoretical basis of microbial kinetics and bioenergetics
- Detailed knowledge of carbon, nitrogen, sulfur, and selected metal (Fe, Mn, Cr, U, As, …) geochemistry and geomicrobiology
- Basic knowledge of contaminant hydrology and bioremediation

4. Mineral surface geochemistry

- Mineral structure and crystal chemistry of common oxides, silicates and carbonates
- Structure of mineral surfaces, surface complexation theory
- Theories of mineral nucleation, growth and dissolution

5. Organic geochemistry

- Methods of isolation of dissolved organic matter (DOM) from natural waters
- Structure, composition and properties of natural (DOM) in freshwater and marine environments
    - Elemental composition of DOM
    - ^{1}H and ^{13}C NMR spectroscopy of DOM
    - FTICR mass spectra of DOM
    - Analyses of biomolecules in DOM (amino acids, sugars, fatty acids, etc.)
- Detailed understanding of the role of DOM in metal complexation and acid-base chemistry of natural waters

6. Geochemical modeling

- Working knowledge of at least one programming language (Fortran, C++, …) or one mathematical software environment (e.g., MATLAB)
- Derivation and implementation of mass conservation equations for multi-component reaction-transport systems (PDEs)
- Finite difference, finite element numerical calculations

Essential Knowledge List for Paleoceanography/Paleoclimatology Students

Minimum Recommended Coursework (students need to know the material covered)

Paleoceanography/Paleoclimatology
Oceanography
Introduction to Climate Change
Isotope Geochemistry
Ocean Biogeochemical Cycles

Extended Coursework (students need to know the material of the courses they selected to best complement their research area). This might include more advanced coursework in ocean/atmosphere dynamics, geochemistry, numerical methods, etc.

If you know the material presented in these courses well and done some extra reading in areas close to your research project, you will do well on your general qualifying exam.

A. General Earth Science Knowledge (to the level presented in an undergraduate non-majors class)
How and when did the earth form, basic earth structure
Basics of Plate Tectonics, Earthquakes
Rock cycle and chemical composition of earths
Basic Earth History
Atmospheric and Ocean composition
Greenhouse effect and global warming
Recent exciting developments

B. General Climate Knowledge
Global energy balance (including albedo, greenhouse gasses)
Global scale atmospheric circulation patterns
Seasonality and monsoons
Atmospheric composition, clouds, aerosols
Role of ocean in climate
ENSO & coupled ocean-atmosphere phenomenon

C. General Oceanographic Knowledge
Wind driven circulation (Ekman transport/upwelling/convergence, Gyre circulations)
Major ocean currents (where and why)
Deepwater formation (where and why)
Deepwater circulation patterns

D. Ocean Biogeochemistry
Primary production (where, why, what organisms)
Distribution of major nutrients
Role of trace elements
Gas solubility and air-sea exchange
Distribution of oxygen
Carbon cycle

- Speciation
- Air-sea exchange
- Carbonate solubility

Ocean sediments (major components and controls on composition)

E. Isotope Geochemistry
Oxygen isotopes in water (atmosphere, freshwater, ocean) and carbonates
Carbon isotopes in the environment (DIC, organic matter, carbonates)

Basics of mass spectrometry including calibration
Carbon-14 and U-series dating

F. Paleoclimate Methods
Familiarity with proxies (how they work, strengths and weaknesses, geographic and temporal limitations) for:

- Marine records (sediment cores, corals), Terrestrial records (ice cores, stalagmites, groundwater, etc.)
- Proxies include, isotopic, sedimentological, ecological, biochemical, trace elements, noble gases, etc.

Paleoclimate modeling – boundary conditions, forcing, coupling, hierarchy of models
Timescales/chronologies -- methods, limitations, controversies

G. Climate History
Knowledge of basic state of ocean/atmosphere system, how we know what we know, ideas about reasons for changes
Holocene climate variability
The last deglaciation and abrupt climate change during MIS Stage 3
LGM
Pleistocene glacial cycles
Cenozoic "deterioration"
Cretaceous climate
Early evolution of ocean/atmosphere/climate

H. Controls on Past Climate
What processes drive climate change? What are feedbacks that are active on various timescales?
Milankovitch timescales
Longer Term changes (Timescales from billions to millions of years)
Shorter term changes (Millennial, century, decadal)

I. Links to Anthropogenic Climate Change
How does your work relate to anthropogenic global warming? How could your results be used to reduce the uncertainties of future climate projections?

J. Paleoclimate Perspective
Where has the field been? Where is it going? Where does your work fit into the broader picture? What problems are the most pressing? Why?

K. Other Specific Issues Relevant to your Thesis Project
If your research involves corals, know something about coral biology and chemistry. If your research involves planktonic foraminifera, read up on planktonic foraminifera ecology. If your research involves lead isotopes, know in detail about the cycling of lead in the earth system. If your research involves the Atlantic overturning circulation, know the details about what controls this. Etc.

Recommended readings:
Basic Geology text for undergraduate non-majors, Read news sections in *Science* and *Nature* every week.

Dennis Hartmann: Global Physical Climatology
Open University Press: Ocean Circulation
Sarmiento and Gruber: Ocean Biogeochemical Cycles
Gunther Faure: Isotope Geology
Paleoclimate topics: See class assignments for Paleoclimate, read paleoclimate articles in *Science* and *Nature* as they come out. Read relevant reviews published over the past several years.
Paleoceanography, GRL, EPSL, GCA, Journal of Climate: Read articles relevant to your research

Essential Knowledge List for Cryosphere Students

- **Cryosphere history**
  - Glacial cycles and glacial climate variability including Heinrich events
  - Ice sheets during warm periods (e.g. Eocene)
  - Little ice age
  - Quaternary ice sheets (e.g. Laurentide)
- **Glacier geophysics**
  - Ice-penetrating radar sounding
  - Seismic refraction and reflection
  - Electromagnetic and resistivity
- **Surface mass balance**
  - Greenland vs Antarctica vs mountain glaciers
  - Equilibrium line altitude
  - Surface energy balance
- **Ice deformation**
  - Continuum mechanics
  - Stress and strain
  - Glen's law and variants
  - Fabric effects in glacier ice
  - Viscous, plastic, elastic and other material rheologies
- **Ice flow**
  - Force balance
  - Stokes flow and approximations therein
  - Grounding lines and marine ice sheet stability
  - Buttressing and bridging effects
- **Temperature and heat in ice sheets**
  - Energy and heat equation
  - Steady-state temperature profiles
  - Temperate ice
- **Glacier hydrology**
  - Supra- vs. en- vs. sub-glacial drainage types
  - Surface and basal crevasses
  - Cavities vs R channels
  - Flow through porous media in ice/firn/sediments
- **Glacier-bed interactions**
  - Weertman's sliding law
  - Cavitation and regelation
  - Till deformation
  - Soft-bed vs hard-bed sliding
- **Sea level**
  - History of global sea level change
  - Future sea level projections
  - Sea level equation
  - Glacial isostatic adjustment

- **Ice-Ocean Interactions**
  - Three-equation parameterization
  - Calving and fracture mechanics
  - Thermohaline circulation
  - Major water masses around Antarctica and Greenland
  - Sea-ice formation
  - Ice pump
- **Remote sensing**
  - Electromagnetic properties of snow/firn/ice
  - Visible/near-IR imaging
  - Laser and radar altimetry
  - Synthetic aperture radar
  - Passive and active microwave theory
- **Climate and ocean dynamics**
  - Equations of mass, momentum, state, and energy in a rotating frame of reference
  - Global energy balance, surface energy balance, radiative transfer and climate
  - Hydrological cycle
  - Global atmospheric circulation
  - Climate variability (e.g. interannual to millenial time scales)
  - The role of the ocean in climate change
  - Surface exchange of heat and moisture, energy and salinity budget, ocean mixed layer
  - Steady and seasonal ocean circulation, waves, tides, currents, shallow water processes.
  - Physical oceanography of major current systems (e.g. gyre-scale circulations, boundary current systems, and tropics)
  - Wave motion in the ocean (e.g. Rossby, Kelvin, internal, and gravity waves)