Glacier and Ice Sheet Dynamics

EAS 4403/8803
Spring 2021

Instructor:	Alexander Robel Winnie Chu	**Time:**	T/Th 12:30 – 1:45 (Online)
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Course Page: https://gatech.instructure.com/courses/181162

Course description: This course covers the fundamentals of glacier and ice-sheet dynamics and their application to problems in sea level, paleoclimate, and planetary science. Course content includes glacier mass balance, the material properties and rheology of ice, the basic equations of ice- sheet and -shelf flow, basal processes, the stability and history of ice sheets. This course is targeted at graduate students in climate, geophysics and planetary sciences, but is also appropriate for any undergraduate student with sufficient interest and prerequisite understanding of undergraduate-level mathematics and Earth sciences.

Prerequisites: An undergraduate-level understanding of calculus and differential equations. Some introductory ability with simple programming (MATLAB or Python preferably).

Course Goals and Learning Outcomes: At the end of this course, students should be able to read literature in glaciology and have an understanding of the important ideas in the fields. Students should be able to build simple ice sheet models and interpret output from complex ice sheet models. Students should have an understanding of the most relevant observations constraining our understanding of ice sheet processes and be able to perform simple analysis of glaciological data sets.

Course References: There is no single textbook for our class that you need to purchase. This is a non-exhaustive list of various interesting and useful books that you may need to consult occasionally.

- K.M. Cuffey and W.S.B Paterson, *The Physics of Glaciers*, B-H, 4th ed., 2010.
- C.J. van der Veen *Fundamentals of Glacier Dynamics*, CRC Press, 2nd ed., 2013.
- R. LeB. Hooke, *Principles of Glacier Mechanics*, Cambridge U Press, 2nd ed., 2005.

Downloadable versions (earlier eds) of Cuffey (link) and van der Veen (link) are available from GT library.

Course Requirements and Grading: Problem sets every 2 weeks (60%), final project (25%), final project talk & participation (15%).

Problem sets are meant to challenge you to think like a scientist about a problem that you have never seen before using math, simple coding, or data analysis. Though figuring out an approach and solution to these problems may take some time, if you feel stuck or think the problem is incorrectly posed, please send me an e-mail or see me in office hours.

Final projects will be on a topic of your choosing and involve reproducing a result from an ice-related paper and extending it, or applying an idea learned from class to a new problem. Projects at the interface of glaciology and geophysics, climate or planetary sciences are allowed/encouraged. Projects will be due on the last day of class and the last two class sessions will be devoted to short (7 minute) lightning talks on the project. To encourage participation and discussion of the lightning talks, everyone will prepare questions ahead of time to ask presenters on the day that they are not presenting.

Grading Scale: A: 90-100%, B: 80-90%, C: 70-80%, D: 60-70%, F: 50-60%

Tentative Course Schedule:
Assignments in red. Supporting reading in blue (CP=Cuffey & Paterson, VDV = van der Veen).

Week 01 Preliminaries: what is a glacier, where are glaciers, history of ice on Earth, glacial cycle models (CP Ch. 13.3)

Week 02 Surface mass balance: accumulation, ablation, equilibrium line, height-mass balance feedback, firn compaction, simple mountain glacier models (CP Ch. 2, 4-5, 11) (Assignment 1 due Jan. 28)

Week 03 Ice flow: the continuity/advection equation, continuum mechanics, stress and strain, constitutive laws, plastic/viscous/non-newtonian flow (VDV Ch. 1-2, CP Ch. 3)

Week 04 Ice flow: Cauchy momentum equation, Stokes flow, the many flow approximations, how ice sheet models work (VDV Ch. 3) (Assignment 2 due Feb. 16)

Week 05 Ice temperature: thermal classification of glaciers, heat equation, steady-state approximation (VDV Ch. 6, CP Ch. 9)

Week 06 Ice-bed interface: cavitation, regelation, till (CP Ch. 7, VDV Ch. 7) (Assignment 3 due March 4)

Week 07 Hydrology: supra-, en- and sub-glacial drainage systems, drainage models, flow through porous media (CP Ch. 6)

Week 08 Ice streams, Marine ice sheets (CP Ch. 8) (Assignment 3.5 (project proposal abstract) due March 18)

Week 09 Ice-Ocean interactions, Fracture (Assignment 4 due March 30)

Week 10 Remote sensing of ice sheets: satellites, airborne methods

Week 11 Glacial geophysics: ice-penetrating radar, seismic methods

Week 12 Sea Level: gravity, glacial isostatic adjustment, future sea-level rise

Last class Final Project lightning talks (7 minutes talk + 7 minutes discussion) (final project reports due Tuesday 4/27)

Collaboration & Group Work
You may find it useful to discuss assignments with your fellow students. The course policy is that discussion is acceptable if the goal is to determine an approach to a possible solution. However, sharing/comparing complete solutions is not allowed, including code, derivations or plots from your final write-up.

Attendance and/or Participation
Attendance is not required. However, a considerable portion of the course material will be covered in the class session. Though textbooks support these lectures, they cannot exactly replace the material covered in lecture. If you plan on missing multiple class session in a row, please e-mail me ahead of time.

Extensions, Late Assignments, & Re-Scheduled/Missed Exams
Late assignments will only be accepted without penalty if you have asked for permission (with reason) at least 24 hours before the assignment is due with a proposed date of submission. Otherwise, assignments submitted later than the end of class time on the day that they are due will automatically be deducted 20% credit. Assignments will not be accepted more than 24 hours late (i.e. you will receive no credit for the assignment) unless you have received prior permission.

Student Use of Mobile Devices in the Classroom
You are allowed to use whatever tool (laptop, tablet, etc.) you need in class to take notes and generally be successful. However, unless you have asked me ahead of time to be able to use your phone during class (to take notes or for emergency purposes), using your phone in class is not permitted. If any emergency comes up unexpectedly in class that requires you to use your phone, please let me know.

Academic Integrity
Georgia Tech aims to cultivate a community based on trust, academic integrity, and honor. Students are expected to act according to the highest ethical standards. For information on Georgia Tech's Academic Honor Code, please visit http://www.catalog.gatech.edu/policies/honor-code/ or http://www.catalog.gatech.edu/rules/18/. Any student suspected of cheating or plagiarizing on a quiz, exam, or assignment will be reported to the Office of Student Integrity, who will investigate the incident and identify the appropriate penalty for violations.

Accommodations for Students with Disabilities
If you are a student with learning needs that require special accommodation, contact the Office of Disability Services at (404)894-2563 or http://disabilityservices.gatech.edu/, as soon as possible, to make an appointment to discuss your special needs and to obtain an accommodations letter. Please also e-mail me as soon as possible in order to set up a time to discuss your learning needs.

Student-Faculty Expectations Agreement
At Georgia Tech we believe that it is important to strive for an atmosphere of mutual respect, acknowledgement, and responsibility between faculty members and the student body. See http://www.catalog.gatech.edu/rules/22/ for an articulation of some basic expectation that you can have of me and that I have of you. In the end, simple respect for knowledge, hard work, and cordial interactions will help build the environment we seek. Therefore, I encourage you to remain committed to the ideals of Georgia Tech while in this class.

Statement of Intent for Inclusivity
As a member of the Georgia Tech community, I am committed to creating a learning environment in which all of my students feel safe and included. Because we are individuals with varying needs, I am reliant on your feedback to achieve this goal. To that end, I invite you to enter into dialogue with me about the things I can stop, start, and continue doing to make my classroom an environment in which every student feels valued and can engage actively in our learning community.

Campus Resources for Students
In your time at Georgia Tech, you may find yourself in need of support. Below you will find some resources to support you both as a student and as a person.

Academic support

- Center for Academic Success (http://success.gatech.edu)
  - 1-to-1 tutoring http://success.gatech.edu/1-1-tutoring
  - Peer-Led Undergraduate Study (PLUS) http://success.gatech.edu/tutoring/plus
  - Academic coaching http://success.gatech.edu/coaching
- Residence Life's Learning Assistance Program (https://housing.gatech.edu/learning-assistance-program)
  - Drop-in tutoring for many 1000 level courses
- OMED: Educational Services (http://omed.gatech.edu/programs/academic-support)
  - Group study sessions and tutoring programs
- Communication Center (http://www.communicationcenter.gatech.edu)
  - Individualized help with writing and multimedia projects
- Academic advisors for your major (http://advising.gatech.edu/)

Personal Support

- The Office of the Dean of Students: http://studentlife.gatech.edu/content/services; 404-894-6367; Smithgall Student Services Building 2nd floor
  - You also may request assistance at https://gatech-advocate.symplicity.com/care_report/index.php/pid383662?
- Counseling Center: http://counseling.gatech.edu; 404-894-2575; Smithgall Student Services Building 2nd floor
  - Services include short-term individual counseling, group counseling, couples counseling, testing and assessment, referral services, and crisis intervention. Their website also includes links to state and national resources.
  - Students in crisis may walk in during business hours (8am-5pm, Monday through Friday) or contact the counselor on call after hours at 404-894-2204.
- Students' Temporary Assistance and Resources (STAR): http://studentlife.gatech.edu/content/need-help
  - Can assist with interview clothing, food, and housing needs.
- Stamps Health Services: https://health.gatech.edu; 404-894-1420
  - Primary care, pharmacy, women's health, psychiatry, immunization and allergy, health promotion, and nutrition
- OMED: Educational Services: http://www.omed.gatech.edu
- Women's Resource Center: http://www.womenscenter.gatech.edu; 404-385-0230

- LGBTQIA Resource Center: http://lgbtqia.gatech.edu/; 404-385-2679
- Veteran's Resource Center: http://veterans.gatech.edu/; 404-385-2067
- Georgia Tech Police: 404-894-2500