CLASP 474: Ice sheets and climate

Class details
Instructor: Dr. Jeremy Bassis
Office location: Discord
Office hours: TBD
Class Times: TR 12:00-1:30PM
Class location: Zoom and Discord

About me
How to address me: Jeremy
Preferred pronouns: He/Him/His
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Office hours: Online anytime, send me a message on Discord

Classes held on Zoom and Discord
Zoom link: https://umich.zoom.us/j/96783086295
password: CLASP474
Discord link: https://discord.gg/UuWqbex7eS

Course Overview: Ice sheets and glaciers form an important component of our climate system, both responding to and shaping the Earth's climate system. In this class we will learn about how glaciers and ice sheets worldwide are changing and likely to continue to change in response to climate change. We will investigate the mechanisms and processes that link glacier change to climate and look at real world examples of rapid change and the impact it has on local communities.

Why me, why this course? I study ice sheets and glaciers and how ice changes in response to climate change. I'm interested in how sea level rise affects vulnerable populations and have done fieldwork in Greenland and Antarctica, but most of my current research revolves around building computer models. I love talking about ice and the processes that control how ice flows and fractures.

Disability: Don't hesitate to bring any issues or requests for accommodations to my attention. The virtual learning environment presents new challenges, opportunities and obstacles that we are all learning to navigate together. The University of Michigan is committed to providing equal opportunity for participation in all programs, services and activities. Request for accommodations by persons with disabilities may be made by contacting the Services for Students with Disabilities (SSD) Office located at G664 Haven Hall. The SSD phone number is 734- 763-3000. Once your eligibility for an accommodation has been determined you will be issued a verified individual services accommodation (VISA) form. Please present this form to me at the beginning of the term, or at least two weeks prior to the need for the accommodation (test, project, etc...).

Health and wellbeing: We embark on this adventure in the midst of a pandemic surrounded by upsetting social turmoil. I encourage all of you to consider using resources available at the CARE center. I encourage you to contact me by email or Discord so that we can plan and I can help identify additional resources.

Class Conduct: A positive learning environment relies upon creating an atmosphere where diverse perspectives can be expressed. This is especially challenging in the mixed virtual environment that we will experience this semester. Each student is encouraged to

take an active part in class discussions and activities. Honest and respectful dialogue is expected, especially on the virtual chat sessions that we will work with. Disagreement and challenging of ideas in a supportive and sensitive manner is encouraged. Just as we expect others to listen attentively to our own views, we must reciprocate and listen to others when they speak, especially when we disagree with them. You are all encouraged to work together to learn the material.

What do <u>you</u> need to be successful in this class? Student enrolled in this class come from a variety of backgrounds, majors, experiences. Some parts of this class might be review of material you have already seen while other parts might challenge your comfort zone. This is especially true when we derive and talk about some of the mathematics that we need to use to describe ice sheet motion. There are no prerequisites, but we will look at real data and some familiarity with Excel, MATLAB, R or some other means of reading and displaying data will be useful, but not required.

The following are some guidelines to help you be successful in this class.

<u>Don't panic.</u> To describe ice, we will need to learn a little bit about what a tensor is, how to manipulate them and "invariants" of tensors. We will also need to solve simple differential equations. If you haven't seen this type of math, then don't panic. Some portions of the lectures may be challenging but focus on the applications and big picture concepts that will be revisited in assignments.

<u>Attend classes</u>. We will use class time to work on projects, assignments and have discussions. Attending and participating in discussions is an important part of the learning environment. Missing a class or two is not a problem and can be made up, but missing many classes means that you will miss content.

<u>Ask for help.</u> Contact me outside of class (email, Discord, carrier pigeon) if you need help or need to miss class. Lots of unexpected things can happen during the semester. Let me know if you are struggling, need extensions on assignments or are just confused. Letting me know that you need help or are struggling means that we can work together to make sure you are on a path to be successful.

<u>Ask lots of questions</u>. Ask questions when you don't understand. Ask questions when you think I'm wrong. Ask questions when you think you understand but aren't sure. Ask questions about things that you have read and about things that we haven't talked about that you would like to talk about.

<u>Do the assignments</u>. We will have a variety of assignments, including group projects. The assignments are designed to force you to apply material you have learned in class. Some of assignments are going challenge you and that is the point. Some assignments are (hopefully) easy. Don't get frustrated. Not everything is going to be easy. Ask for help if you get confused, lost or stumped. Challenging assignments will often have class time and/or involve group work. Use this time to work on the assignments.

Be respectful. We will do a lot of in class discussions and group assignments. Take time to listen to everyone. Try not to let any one person crowd out others from the conversation. Use people's preferred pronouns. Come with good intentions and assume good intentions.

Hold me accountable and hold yourself accountable. Learning is challenging and virtual learning introduces new obstacles. I will do my best to make sure everyone's learning needs are met. If you need any accommodations to make learning environment is not work for you, let me know so that we can problem solve how to fix it.

Different ways to be successful in this class. Many of you come from different majors. We have undergraduate and graduate students, engineers and scientists. Some of you are taking this course as a technical elective, some might want to pursue a career related to icy climate, others are just ice curious. Each of you is taking this class for a different reason. What you get out of this class is going to depend on how deep you want to go.

Birds-eye view: You are interested in a roadmap of the current state of the cryosphere and be able to explain feedbacks between ice and climate and the impact these cryospheric changes have on society. You will be able to read, discuss and evaluate papers discussing current topics related to ice and climate. You won't necessarily follow the details of all of the mathematical derivations, but be able to explain concepts and big picture ideas. You can take part in the larger climate conversation.

Explorer: You are interested in diving deeper into the details and learning about the processes that control ice sheet demise at a more quantitative level. You follow and can reproduce many of the mathematical derivations and/or dig deeper into the details of some of the measurement techniques. You may select more ambitious projects during the semester that involve more quantitative analysis, programming or interpretation and you may attempt some of the extra credit more challenging assignments.

Connoisseur: You want to not only dig into processes, but also be able to explain assumptions and limitations of our theories. You follow the mathematical derivations, but also challenge some of the assumptions and can analyze weaknesses in current models and theories. You may select more ambitious projects during the semester and embrace the extra credit assignments.

Learning objectives and skills. Our focus is on ice, but this is a science class and build on general physical science competencies. The big picture learning objectives for all students includes the following.

1. ***Read, interpret and evaluate current literature***. Our climate is rapidly changing in response to human emissions. Mitigating and adapting to climate change remains one of the most pressing societal issues. You will participate in that larger conversation, be able to analyze and use the scientific method to critically interpret new scientific results.

2. ***Data analysis, visualization and interpretation***. We will read and analyze data. This will involve writing small computer programs (or if you really insist Excel) and visualize and interpret this data by plotting it.

3. ***Describe and explain the big questions in glaciology***. Unlike many areas of science and engineering, glaciology is relatively new. This means many topics, like the "marine ice cliff instability", "sliding laws" remain controversial.

Content covered:
Because this class can evolve based on student interest, background and current events, we will maintain flexibility in our schedule. Each learning section will have a couple of short learning assessments to test major concepts and terminology coupled with a longer homework assignment or mini project that involves some data analysis, visualization or running existing models. Below, we sketch out the different modules.

Module 1 Glacier and ice sheet mass balance: (1 month)
- Ever wonder why most glaciers are retreating and losing mass, but glaciers in a few regions are gaining mass? Students in this class will identify the processes and mechanisms responsible for determining glacier mass balance and be able to explain how these processes are related to climate. This will include examining the energy balance at the surface of a glacier that controls how quickly glaciers melt learning nifty new terminology like the equilibrium line altitude (ELA)
- Students will plot and analyze global glacier mass balance data and relate observed changes to regional and global climate change. Doing this will require that students visualize and interpret data and explain data to others, providing the foundation for successful conversations at parties.

Assignments and Assessments:
Projects:

Module 2 Ice Sheet Rheology: (2 weeks)
- Rheology tells us how stress causes objects to deform. This is important because ice flows (like a pancake) and rheology tells us how to describe it.
- Using nifty knowledge of tensors, we will learn about laboratory experiments that show how stress in ice causes ice to flow and the relationship between stress and strain rate called "Glen's flow law"

Assignments and Assessments:
Projects:

Module 3 Ice dynamics: (1 month)
- We will express conservation of mass as a partial differential equation through a general equation called the ice thickness equation. Although, technical this is the basis for a mathematical representation of how ice changes shape.
- We will write down expressions for the forces causing ice to flow called the "driving stress". This force balance allows us to write down equations that describe the forces acting on the glacier and causing it to deform.

- We will learn that friction between the bottom of the ice and ground limits how fast ice can flow and will learn just enough jargon to read current literature that explains how little we know about friction.

Assignments and Assessments:
Projects:

Module 4 Ice-ocean interaction and iceberg calving (2 weeks)

- Ice in contact with the ocean also melts and we will examine observations of the role of melting in driving current ice sheet changes.
- We will explain and provide sketches of the main processes at work causing ice to melt, like the "ice pump".
- Be able to explain the difference between "warm" ocean cavities, like those in the Amundsen Sea Embayment as opposed to those in the Ross Sea.
- Be able to sketch out basic ocean currents that bring heat to the margins of the Antarctic Ice Sheet and Greenland Ice Sheet

Assignments and Assessments
Projects:

Module 5 Ice sheet stability (2 weeks)

- Be able to explain concepts like the marine ice sheet instability and marine ice cliff instability and relate these instabilities to the West Antarctic Ice Sheet and be able to read and interpret current literature on the field.

Assignments and Assessments
Projects:

More information . . .

Reading resources:
The Physics of Glaciers, 4th edition by Cuffey and Paterson
The Physics of Glaciers, 3rd edition by Paterson
Principles of Glacier Mechanics, 2nd edition, Roget LeB Hooke
Fundamentals of Glacier Dynamics (C.J. van der Veen, 1999)
Ice Sheets and Climate (Oerlemans and van der Veen, 1984)

Grading Rubric*:		
	Problem sets:	25%
	Individual/group projects	25%
	Written reports:	15%
	Oral presentations:	20%
	Participation**:	15%

*Extra credit is available upon request.

Homework Assignments: Assignments may be done collaboratively, but every group member must turn in the assignment. Stuff happens and if you are unable to turn in an assignment on time please try to contact me before the assignment is due so that we can make arrangements. Late penalties will otherwise apply to assignments that are turned in after the due date.

Individual/group assignments: Some assignments will be done collaboratively as part of a group project. We will have class time to work on some of these projects. You can turn in a single assignment for these group projects.

Oral presentations: Students will prepare and lead class discussion of selected topics.

Participation: A portion of class each week will be dedicated to reading and discussion seminar current and historical papers in glaciology. Your participation grade will be determined by participation in these discussions.

Honor Code: You are free to collaborate with fellow class times on homework and labs, but the work you turn in must be your own, including code. When working collaboratively on code, you must credit classmates with section of code/algorithms obtained from others. Failure to do so will result in an honor code violation and will be forwarded to the honor council for investigation.