ENGG 139.02: Polar Science and Engineering:
Physics & Chemistry of Ice, Polar Glaciology, Remote Sensing

Syllabus

Course Description

This course focusses on three topics relevant to science and engineering within the polar regions of Earth: physics and chemistry of ice, glacial hydrology and remote sensing of polar landscapes., 8-10 lectures in length. Descriptions, faculty and prerequisites are given below.

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Chemistry and Physics of Ice (Emily Asenath-Smith, emily.asenath-smith@dartmouth.edu)
Whether viewed as a beauty or the cause of catastrophe, ice is ubiquitous in nature and has some important properties that result from its unique chemistry and physics. Efforts to control and predict ice accumulation on mechanical and in biological systems or define the fate of pollutants in sensitive polar environments require a fundamental understanding of ice's unique properties. This course will build such a foundation by exploring the materials science of ice and related research topics in the fields of interface physics, biology, and environmental chemistry. By first establishing a common knowledge base for the crystallography, microstructure, and the optical, thermal, and mechanical properties of pure ice, we will then discuss both soluble and insoluble impurities in ice and their effect on the material properties of ice. Course content will culminate with discussions derived from contemporary literature on ice materials science, which includes topics in biological, environmental, and chemical sciences.

Prerequisites: ENGS 24, general chemistry (full year), or permission of instructor.

Lecture 1: Crystal structure and chemistry of pure ice
Lecture 2: Microstructure and characterization of pure ice
Lecture 3: Thermal and mechanical properties of ice materials
Lecture 4: Impurities in ice and their effect on ice thermal and mechanical properties
Lecture 5: Ice in the environment
Lecture 6: Ice on surfaces
Lecture 7: Characterization of buried ice interfaces
Lecture 8: Ice in biological organisms
Lecture 9: Ice in materials synthesis
Lecture 10: Ice as a chemical reaction matrix

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Glacial Hydrology (Carl Renshaw, carl.e.renshaw@dartmouth.edu)
Glacial hydrology is increasingly recognized as an important control on both ice dynamics and the Earth's energy budget. Rapid drainage of glacial lakes impacts basal fluid pressures while the formation of lakes on melting sea ice reduces surface albedo. In both cases the fundamental control on glacial hydrology is ice permeabilty. This module reviews basic concepts of flow through porous media and extends them to consider recent advances in understanding of controls on fluid percolation through heterogeneous and damaged ice. The fate of glacial meltwater is considered through exploration of the ideas of efficient and inefficient basal drainage.

Prerequisites: Math 23

Lecture 1: Background and overview of the controls of permeability on sea and land ice properties and dynamics
Lecture 2: Theory of permeability and flow in granular media
Lecture 3: Methods of measuring permeability
Lecture 4: Sea ice permeability and the rule of 5s
Lecture 5: Heterogeneity
Lecture 6: Cracks and flow – applicability of the representative elementary volume
Lecture 7: Fracture mechanics of fluid filled cracks and glacial lake drainage
Lecture 8: Percolation theory and "efficient" versus "inefficient" drainage
Lecture 9: Extension of diffusion flow theory to ice sheets – the role of bed topography
Lecture 10: Fluid flow versus contaminant transport

Remote Sensing of Polar Landscapes (Jonathan Chipman, jonathan.w.chipman@dartmouth.edu)

In this module, students will learn the principles and applications of remote sensing systems for research on high-latitude vegetation, soils, water, and snow/ice. We will examine case studies of the use of optical and microwave imagery from aerial and satellite platforms to characterize biophysical properties of the landscape. Lab activities will focus on methods for analyzing remote sensing imagery to quantify changes in polar environmental systems across a range of scales.

Prerequisite: An introductory course in physical geography, geomorphology, or geographic information science (GIS).

Lecture 1: Optical remote sensing of terrestrial polar environments; sensor design; electromagnetic radiation interactions with surface features
Lecture 2: Characterizing high-latitude vegetation dynamics with optical satellite remote sensing; spectral mixture modeling and other analytical methods
Lecture 3: Quantification of aeolian soil erosion rates with structure-from-motion photogrammetry
Lecture 4: Monitoring water storage in high-latitude tundra and supraglacial lakes
Lecture 5: Spatiotemporal time series analysis with satellite imagery across scales

Lecture 6: Active and passive microwave remote sensing of polar environments; synthetic aperture radar imaging and altimetry
Lecture 7: Radar polarimetry and interferometry for characterizing surfaces and their evolution over time
Lecture 8: Principles and applications of airborne and spaceborne lidar
Lecture 9: Integration of multisource remote sensing, in-situ observations, and modeling for polar landscape science

Course Learning Outcomes

In this course, students will:

- LO #1: become familiar with character and nature of the phenomena under discussion;
- LO #2: become competent in quantitatively modeling the phenomena in terms of physical processes;
- LO #3: become familiar with the practical impact of the phenomena and competent in suggesting engineering solutions to applied problems.

Methods & Philosophy

Lectures will be given by experts on each of the topics under discussion. As well, students will read selected articles from the literature, discuss them in class and write a term paper on a sub-topic related to the theme of the module.

Expectations & Norms

Students are expected to engage fully in the topic under discussion. This includes reading assigned literature ahead of class and participating in class discussion. Faculty will be available during prescribed office hours and when students need individual assistance.

Class Climate & Inclusivity

Students and faculty are expected to show respect for each other.

Texts & Materials

Texts and materials will be assigned by the member of the faulty teaching the modules.

Assessment & Grading

Grading will based upon an end-of-module exam, the module paper and class participation.

Dartmouth Policies

Student Accessibility and Accommodations

Students with disabilities who may need disability-related academic adjustments and services for this course are encouraged to see the instructor privately as early in the term as possible. Students requiring disability-related academic adjustments and services must consult the Student Accessibility Services office in Carson Hall 125 or by phone: 646-9900 or email: Student.Accessibility.Services@Dartmouth.edu.

Once SAS has authorized services, students must show the originally signed SAS Services and Consent Form and/or a letter on SAS letterhead to me. As a first step, if you have questions about whether you qualify to receive academic adjustments and services, you should contact the SAS office. All inquiries and discussions will remain confidential.

Religious Observances

Some students may wish to take part in religious observances that occur during this academic term. If you have a religious observance that conflicts with your participation in the course, please meet with your instructor before the end of the first week of the term to discuss appropriate accommodations.

Learning Resources

The scientific and engineering literature.

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