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Climate Modeling and Carbon Management

ENGR 3000 (3 credits)

Iceland: Climate Change and the Arctic

This syllabus is representative of a typical semester. Because courses develop and change over time to take advantage of unique learning opportunities, actual course content varies from semester to semester.

Course Description

This seminar focuses on the analysis and use of climate models in understanding and projecting climate change in the future. Though climate models are based on quantitative data and physical principles and have been shown to reproduce climate projections, they are constantly subjected to more systematic evaluation for higher fidelity. Estimates based on climate variables such as temperature and cloud or cryospheric feedbacks provide high credibility for scientific climate change projections. Though a reliable model of metrics for climate projections is yet to be developed, interactive aerosols are now included in most climate models and substantial progress has been made in the areas of computational methods and the simulation of modes of climate variability. The seminar also addresses issues of gas emission, carbon containment, and management. The focus is on Iceland's innovative experiments with carbon storage and the development of renewable energies. The seminar relies on resources available through program partners including University Centre of the Westfjords, University of Akureyri, University of Iceland, and several scientific institutions around Iceland.

Learning Outcomes

Upon completion of the course, students will be able to:

- Judge the feasibility of existing carbon management strategies/goals and design new targets or strategies to meet goals;
- Use software to generate climate models;
- Analyze climate literature, with the aim of contextualizing literature within its proper field and theoretical background and identifying uncertainties in climate research.

Language of Instruction

This seminar is taught in English, but students will be exposed to vocabulary related to course content through in-country expert lectures and field visits in a wide range of venues and regional locales.

Instructional Methods

SIT's teaching and learning philosophy is grounded in the experiential learning theory developed by Kolb (1984; 2015) and informed by various scholars, such as Dewey, Piaget, Lewin, among others. Experiential learning theory recognizes that learning is an active process that is not confined to the formal curriculum; "knowledge is created through the transformation of experience" (Kolb, 2015, p. 49). Learning involves both content and process. Learning is holistic and happens through various life experiences upon which students draw to generate new ways of knowing and being. Learning involves a community and is a lifelong endeavor. Learning is transformational. The suggested four-step cycle of a *concrete experience*, *reflective observation*, *abstract conceptualization*, and *active experimentation* embedded in the experiential learning model is not linear and might not always happen in that specific order, as any learning is highly context dependent. These stages of taking part in a shared experience, reflecting on that experience by describing and interpreting it, challenging one's own assumptions and beliefs to generate new knowledge, and ultimately applying new knowledge, awareness, skills, and attitudes in a variety of situations and contexts are important for students to engage in to become empowered lifelong learners.

Course Schedule

Students will be provided a detailed course schedule during orientation on the program. Please be aware that topics and excursions may vary to take advantage of any emerging events, to accommodate changes in our lecturers' availability, and to respect any changes that would affect student safety. Students will be notified whenever this occurs.

Module 1: Modeling Arctic Climate Change

This module facilitates students' work with climate data and simulations of the earth's changing climate. It uses insights from physics, chemistry, biology, and earth and atmospheric sciences. The module discusses models of climate systems and analyzes the role of climate simulation and uncertainty in modeling Arctic climate change.

Session 1: Types and Sensitivity of Climate Models

This session provides a general introduction to types of climate models and techniques for assessing model performance. The session also addresses methods used to assess climate sensitivity.

Site Visit: We will learn from a climate modeler at the Icelandic Met Office.

Recommended Reading:

Drake, J. B. (2014). *Climate modeling for scientists and engineers* (Vol. 19). SIAM.

Flato, G., Marotzke, J., Abiodun, B., Braconnot, P., Chou, S. C., Collins, W. J., ... & Forest, C. (2013). Evaluation of climate models. In: climate change 2013: the physical science basis. Contribution of working group I to the fifth assessment report of the intergovernmental panel on climate change. *Climate Change 2013*, *5*, 741-755 (Chapters 9.1 Climate Models and Their Characteristics and 9.2 Techniques for Assessing Model Performance). Retrieved from: https://www.ipcc.ch/pdf/assessment-report/ar5/wg1/WG1AR5_Chapter09_FINAL.pdf

Randall, D. A., Wood, R. A., Bony, S., Colman, R., Fichefet, T., Fyfe, J., ... & Stouffer, R. J. (2007). Climate models and their evaluation. In *Climate change 2007: The physical science basis. Contribution of Working Group I to the Fourth Assessment Report of the IPCC (FAR)*. Cambridge University Press, 629-639 (Chapter 8.6 Climate Sensitivity and Feedbacks). Retrieved from: https://www.ipcc.ch/pdf/assessment-report/ar4/wg1/ar4-wg1-chapter8.pdf

Session 2: Working with Climate Models: Integrated Assessment Modeling

This session focuses on ways in which climate models work and the reliability model predictions for future climate change. The session also addresses climate modeling in the atmosphere and surface warming.

Recommended Reading:

Rasch, P. J. (Ed.) (2015). *Climate Change Modeling Methodology*. Larkspur, CA: Springer.

Skeptical Science. (2012). How do climate models work? Retrieved from: http://www.skepticalscience.com/how-do-climate-models-work.html

Flato, G., Marotzke, J., Abiodun, B., Braconnot, P., Chou, S. C., Collins, W. J., ... & Forest, C. (2013). Evaluation of climate models. In: climate change 2013: the physical science basis. Contribution of working group I to the fifth assessment report of the intergovernmental panel on climate change. *Climate Change 2013*, *5*, 760-794 (Chapter 9.4 Simulation of Recent and Longer-Term Records in Global Models). Retrieved from: https://www.ipcc.ch/pdf/assessment-report/ar5/wg1/WG1AR5_Chapter09_FINAL.pdf

Session 3: Uncertainty and Climate Modeling

This session addresses climate model inadequacy and uncertainty and the importance of understanding the uncertainty in climate predictions. The session focuses on key uncertainties such as greenhouse gas forcing and model inadequacy. The session also analyzes examples of model uncertainty and methods to reduce uncertainty and increase resilience.

Session 4: Integrated Assessment Modeling and Climate Simulation and Analysis

The session addresses the strengths and limitations of integrated assessment modeling and its impact on sustainability. The session also focuses on reliability and efficiency of integrated assessment models in simulating climate change.

Module 2: Geoengineering and Carbon Economics

This module analyzes the greenhouse effect, the carbon cycle, and how fossil fuels affect that cycle. Students survey innovative strategies for a low-carbon built environment. The focus is on Iceland's innovative approach to carbon dioxide management, renewable energy, and the impact of climate change.

Session 1: Low-Carbon Energy Technologies

This session focuses on the development of local-carbon energy technologies and greenhouse gas emissions cuts. The focus is on Iceland's innovative approach and EU and global climate objectives. The session also addresses low-carbon energy development in the particular area of built environment.

Site Visit: In this session, we look at Iceland's vast geothermal and hydropower resources that are used for space heating and powering the electrical grid.

Recommended Reading:
Emmanuel, R., & Baker, K. (2012). *Carbon management in the built environment*. Routledge.

Session 2: Development of Non-fossil Energy Systems
This session is focused on the discussion of the non-fossil energy systems as they relate to a limited fossil energy, increasing energy demand, and global warming. The session also addresses the development of non-fossil energy technologies and policy.

Site Visit: In this session, we will visit hydropower dams and geothermal power plants, depending on seasonal accessibility.

Recommended Reading:
Narbel, P. A., Hansen, J. P., & Lien, J. R. (2014). *Energy technologies and economics*. Springer. (Chapter 1: Basic Physical Processes and Economics and Chapter 2: Fossil Energy Systems).

Session 3: Innovation and Carbon Dioxide Management
This session will look at the innovative CarbFix project that dissolves CO_2 in water and injects it into basalts where it mineralizes for permanent storage.

Recommended Reading:
Fountain, H. (2015).Turning Carbon Dioxide into Rock, and Burying It. In *The New York Times.* Retrieved from: http://www.nytimes.com/2015/02/10/science/burying-a-mountain-of-co2.html?_r=0

Session 5: Marine Renewable Energy
This session explores the benefits of offshore wind, wave, and tidal energy development as renewable energy options. Students assess the promise and challenges of these energy options through field visits and interactions with the community of local experts.

Recommended Reading:
International Energy Authority Renewable Energy Technology Deployment (IEA-RETD). (2012). *Offshore Renewable Energy: Accelerating the Deployment of Offshore Wind, Tidal, and Wave Technologies*. Oxford: Routledge. (Chapter 3: Offshore Renewable Energy Technologies).

Module 3: Arctic Energy
This module introduces students to energy topics in the Arctic with a particular focus on tangible case studies and projects in Iceland. Topics include global energy markets, Arctic resources, relevant technological developments, associated environmental risks, and impacts on Arctic communities.

Session 1: Arctic Energy Resources

This session addresses energy potential of the Arctic, including projected quantity and location of oil and gas reserves. The session engages with the question of how the Arctic's energy resources will contribute to the global energy mix in the decades to come.

Recommended Reading:

Schaeffer, R., Szklo, A. S., de Lucena, A. F. P., Borba, B. S. M. C., Nogueira, L. P. P., Fleming, F. P., ... & Boulahya, M. S. (2012). Energy sector vulnerability to climate change: a review. *Energy*, *38*(1), 1-12.

Session 2: Arctic Oil and Gas Exploration

This session focuses on the recent and projected development of oil and gas exploitation in the Arctic.

Required Reading:

Arctic Council (2009): Arctic Council Offshore Oil and Gas Guidelines. Retrieved from: http://www.govmin.gl/images/stories/petroleum/Arctic_Offshore_Oil_and_Gas_Guidelines_2009.pdf

Session 3: Renewable Energy Potential in the Arctic

This session provides a comprehensive overview of the future potential of renewable energy sources and the role of alternative energy systems and the new Arctic portal. The session is led by a representative from Vistorka, the organization working to provide environmental solutions to waste products in the region. They take us to see several of the ongoing projects that have helped make Akureyri carbon neutral.

Required Reading:

Aslani, A., Naaranoja, M., & Wong, K. F. V. (2013). Strategic analysis of diffusion of renewable energy in the Nordic countries. *Renewable and sustainable energy reviews*, *22*, 497-505.

Session 4: Renewable Energy Potential Around the world

This session explores areas outside the Arctic and their potential for using renewable resources. The session looks at how there might be potential for strategies developed in the Arctic to be applied globally and vice versa.

Required Reading:

Aslani, A., Naaranoja, M., & Wong, K. F. V. (2013). Strategic analysis of diffusion of renewable energy in the Nordic countries. *Renewable and sustainable energy reviews*, *22*, 497-505.

Assignments and Evaluation

Papers will be graded on style and structure, depth of analysis, and synthesis of secondary and primary sources.

Assignment Descriptions and Evaluation

1) Carbon Footprint Assignment (45%)
Students will analyze carbon footprints at three scales, create carbon scenarios for all scales, and determine the most efficient level of implementation.

2) Climate Modeling Assignment (45%)
Students will find an example of a climate paper in the literature and run the same climate scenario. Student results will be compared to published results and efficacy and discrepancies will be evaluated.

3) Participation (10%)
This includes active involvement in lectures, readings, discussions, and excursions using the following criteria:

- Attendance - promptness to class and positive presence in class.
- Active Listening - paying attention in class and during field excursions, asking appropriate questions, showing interest and enthusiasm (this includes body language), entertaining contradictory perspectives, taking notes.
- Involvement in Class Discussions - either in small or large groups, sharing knowledge. This means challenging yourself to speak up if you usually don't, and also means allowing others to speak if you are a person who tends to dominate class discussions.
- Group Accountability – positive participation in the group during field excursions and classes; not keeping others waiting.
- Displaying Respect – culturally appropriate interaction with hosts, SIT program staff, SIT lecturers and communities.

Assessment

Carbon Footprint Assignment - 45%
Climate Modeling Assignment - 45%
Participation - 10%

Attendance and Participation
Due to the nature of SIT Study Abroad programs, and the importance of student and instructor contributions in each and every class session, attendance at all classes and for all program excursions is required. Criteria for evaluation of student performance include attendance and participation in program activities. Students must fully participate in all program components and courses. Students may not voluntarily opt out of required program activities. Valid reasons for absence – such as illness – must be discussed with the academic director or other designated staff person. Absences impact academic performance, may impact grades, and could result in dismissal from the program.

Late Assignments
SIT Study Abroad programs integrate traditional classroom lectures and discussion with field-based experiences, site visits and debriefs. The curriculum is designed to build on itself and progress to the culmination (projects, ISP, case studies, internship, etc.). It is critical that students complete assignments in a timely manner to continue to benefit from the sequences in assignments, reflections and experiences throughout the program.

Example: Students may request a justified extension for one paper/assignment during the semester. Requests must be made in writing and at least 12 hours before the posted due date and time. If reason for request is accepted, an extension of up to one week may be granted at that time. Any further requests for extensions will not be granted. Students who fail to submit the assignment within the extension period will receive an 'F' for the assignment.

Grading Scale

94-100%	A
90-93%	A-
87-89%	B+
84-86%	B
80-83%	B-
77-79%	C+
74-76%	C
70-73%	C-
67-69%	D+
64-66%	D
below 64%	F

Program Expectations

- Show up prepared. Be on time, have your readings completed and points in mind for discussion or clarification. Complying with these elements raises the level of class discussion for everyone.
- Have assignments completed on schedule, printed, and done accordingly to the specified requirements. This will help ensure that your assignments are returned in a timely manner.
- Ask questions in class. Engage the lecturer. These are often very busy professionals who are doing us an honor by coming to speak.
- Comply with academic integrity policies (no plagiarism or cheating, nothing unethical).
- Respect differences of opinion (classmates', lecturers, local constituents engaged with on the visits). You are not expected to agree with everything you hear, but you are expected to listen across difference and consider other perspectives with respect.
- Storing Your Work: Keep several copies of your work as back up and keep one copy accessible to you through an online forum, such as an attachment in your email, the course learning management system, or cloud-based storage. This way your work will always be available to despite technical issues. Lost files, deleted drives, or computer crashes are not excuses for late, missing work.
- Personal Technology Use: Cell phones and other personal electronics can be used for taking notes and other class activities. Off-task usage is not acceptable. You may be marked as absent for habitually using them for something other than classroom activities.
- Content Considerations: Some texts and activities you will encounter in this course delve into sensitive topics that may be emotionally and intellectually challenging. Our classroom is a space where we can engage with challenging ideas, question assumptions, and navigate difficult topics with respect and maturity. As possible, I will flag content and activities that are especially graphic or intense, so we are prepared to

address them soberly and sensitively. If you are struggling to keep up with the work or participate in the course because of the nature of the content and activities, you should speak with me and/or seek help from counseling services.

- Classroom recording policy: To ensure the free and open discussion of ideas, students may not record classroom lectures, discussion and/or activities without the advance written permission of the instructor, and any such recording properly approved in advance can be used solely for the student's own private use.

SIT Policies and Resources

Please refer to the SIT Study Abroad Handbook and the Policies section of the SIT website for all academic and student affairs policies. Students are accountable for complying with all published policies. Of particular relevance to this course are the policies regarding: academic integrity, Family Educational Rights and Privacy Act (FERPA), research and ethics in field study and internships, late assignments, academic status, academic appeals, diversity and disability, sexual harassment and misconduct, and the student code of conduct.

Please refer to the SIT Study Abroad Handbook and SIT website for information on important resources and services provided through our central administration in Vermont, such as Library resources and research support, Disability Services, Counseling Services, Title IX information, and Equity, Diversity, and Inclusion resources.