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Carbon Management and Climate Modeling

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 carbon management and mitigation, energy use and production in the Arctic, and the analysis and use of climate models in understanding and projecting climate change in the future. The seminar explores Iceland's innovative experiments with carbon storage and fixation and the development of renewable energies, as well as considers the implications of climate projections in the Arctic. 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:

- Generate and analyze climate models and their applications and limitations;
- Compare and contrast renewable and non-renewable energy options and their implications on climate change in the Arctic;
- Evaluate the feasibility of existing carbon management strategies/goals and design new targets or strategies to meet goals;

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.

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

Climate modeling assignment (20%)
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.

Carbon fixation assignment (20%)
Students will measure a local forest and calculate estimated carbon fixation for a given time period in several types of tree species. Results will be compared to published data on tree species in other climates and analysis will consider feasibility of carbon fixation through forestry in Arctic regions.

Program carbon budget (20%)
Students may work individually or in teams to calculate the total carbon footprint of the SIT semester program and then propose a tangible plan to ensure a net-zero future through any combination of reduced emissions or increased fixation, with the ultimate goal of feasible implementation.

Renewable energy proposal (20%)
Students will work in groups to research the feasibility, limitations, and implementation of a renewable energy source and produce a single "pitch page" to promote their assigned renewable energy source. Teams will present/debate with a small audience of local Icelanders to generate discussion of the reality of alternative energy sources.

Field presentation (10%)
Students will research and present on a topic specific to sites visited during the major excursions as appropriate for the given semester to acquire and demonstrate expertise on various concepts relating to course content.

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

- Climate Modeling Assignment - 20%
- Carbon Fixation Assignment - 20%
- Program Carbon Budget -20%
- Renewable Energy Proposal - 20%
- Field presentation - 10%
- 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, Accessibility Services, Counseling Services, Title IX information, and Equity, Diversity, and Inclusion resources.

Course Schedule

**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 if 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: Fundamentals of Climate Models

This session provides a general introduction to types of climate models and techniques for assessing model performance. Instruction is provided primarily through a climate modeler at the Icelandic Meteorological Office.

Required Reading:

Canadell, J. G., Monteiro, P. M., Costa, M. H., Cotrim da Cunha, L., Cox, P. M., Eliseev, A. V., ... & Zickfeld, K. (2023). Intergovernmental Panel on Climate Change (IPCC). Global carbon and other biogeochemical cycles and feedbacks. In *Climate change 2021: The physical science basis. Contribution of working group I to the sixth assessment report of the intergovernmental panel on climate change* (pp. 673-816). Cambridge University Press. pdf

Schoeman, D. S., Gupta, A. S., Harrison, C. S., Everett, J. D., Brito-Morales, I., Hannah, L., ... & Richardson, A. J. (2023). Demystifying global climate models for use in the life sciences. *Trends in Ecology & Evolution*, *38*(9), 843-858. pdf

Session 2: Arctic-specific climate considerations

This session focuses on ways in which climate models are relevant in arctic systems, including glaciers, AMOC, permafrost and albedo. Guest lecturers may include a glaciologist and modeler with the Icelandic Meteorological Office.

Required Reading:

Previdi, M., Smith, K. L., & Polvani, L. M. (2021). Arctic amplification of climate change: a review of underlying mechanisms. *Environmental Research Letters*, *16*(9), 093003. https://iopscience.iop.org/article/10.1088/1748-9326/ac1c29/meta

Schuur, E. A., Abbott, B. W., Commane, R., Ernakovich, J., Euskirchen, E., Hugelius, G., ... & Turetsky, M. (2022). Permafrost and climate change: carbon cycle feedbacks from the warming Arctic. Annual Review of Environment and Resources, 47(1), 343-371. pdf

Taylor, P. C., Boeke, R. C., Boisvert, L. N., Feldl, N., Henry, M., Huang, Y., ... & Tan, I. (2022). Process drivers, inter-model spread, and the path forward: A review of amplified Arctic warming. *Frontiers in Earth Science*, *9*, 758361. https://www.frontiersin.org/journals/earth-science/articles/10.3389/feart.2021.758361/full

Session 3: Applying models and addressing limitations

This session addresses climate model limitations, looking at conflicting studies to highlight assumptions and uncertainties. Students will investigate ways that climate models can be applied and compare outcomes of different models.

Required Reading:

Wagener, T., Reinecke, R., & Pianosi, F. (2022). On the evaluation of climate change impact models. *Wiley Interdisciplinary Reviews: Climate Change*, *13*(3), e772. pdf

Module 2: Arctic Energy

This module introduces students to energy topics in the Arctic with a particular focus on renewable energy projects in Iceland. Students survey innovative strategies for a low carbon environment.

Session 1: Non-renewable energy

This session addresses energy potential of the Arctic, including oil and gas exploitation in the Arctic. 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. Guest lecturer may include an energy researcher from the University of Iceland

Required Reading:

Zhukovskiy, Y., Tsvetkov, P., Buldysko, A., Malkova, Y., Stoianova, A., & Koshenkova, A. (2021). Scenario modeling of sustainable development of energy supply in the Arctic. Resources, 10(12), 124. pdf

Session 2: Renewable energy: Geothermal and Hydroelectric

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 look at Iceland's vast geothermal and hydropower resources that are used for space heating and powering the electrical grid, depending on seasonal accessibility.

Required Reading:
Lund, J. W., & Toth, A. N. (2021). Direct utilization of geothermal energy 2020 worldwide review. *Geothermics*, *90*, 101915. pdf

Session 3: Marine Renewable Energy
This session explores the benefits of onshore and 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.

Required Reading:
Samsó, R., Crespin, J., García-Olivares, A., & Solé, J. (2023). Examining the potential of marine renewable energy: A net energy perspective. *Sustainability*, *15*(10), 8050. pdf

Session 4: 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:
Zhukovskiy, Y., Tsvetkov, P., Buldysko, A., Malkova, Y., Stoianova, A., & Koshenkova, A. (2021). Scenario modeling of sustainable development of energy supply in the Arctic. *Resources*, *10*(12), 124. pdf

Module 3: Carbon Management and Mitigation
This module focuses on Iceland's innovative approach to carbon dioxide management through geoengineering, carbon fixation, and carbon reduction.

Session 1: Geoengineering and innovation
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.

Site Visit: In this session we will visit the CarbFix project site at Hellisheidi.

Required Reading:
Snæbjörnsdóttir, S. Ó., Sigfússon, B., Marieni, C., Goldberg, D., Gislason, S. R., & Oelkers, E. H. (2020). Carbon dioxide storage through mineral carbonation. *Nature Reviews Earth & Environment*, *1*(2), 90-102. pdf

Session 2: Carbon fixation

This session will focus on ways carbon can be removed from the atmosphere and incorporated into biomass through forestry, grasses, and changes in land practices. Students will encounter both the advantages and limitations of this approach in the Arctic, engaging in discourse around carbon credits and impact on local communities.

Site Visit: We will visit forestry and land management sites in collaboration with the Icelandic Forest Service and Soil Conservation.

Required Reading:
Mekonnen, Z. A., Riley, W. J., Berner, L. T., Bouskill, N. J., Torn, M. S., Iwahana, G., ... & Grant, R. F. (2021). Arctic tundra shrubification: a review of mechanisms and impacts on ecosystem carbon balance. *Environmental Research Letters*, *16*(5), 053001. https://iopscience.iop.org/article/10.1088/1748-9326/abf28b/pdf

Session 3: Carbon reduction
In this session, students will consider the impact of land use as a source of emissions and contribution to climate change. Wetlands and permafrost will be addressed, considering practicing to reduce emissions to complement carbon fixation efforts. Guest lecturers may include experts in land use in Iceland.

Site Visit: We will visit sites that have been drained/rewetted to measure and assess impacts.

Required Reading:
Zou, J., Ziegler, A. D., Chen, D., McNicol, G., Ciais, P., Jiang, X., ... & Zeng, Z. (2022). Rewetting global wetlands effectively reduces major greenhouse gas emissions. *Nature Geoscience*, *15*(8), 627-632. pdf