Course Syllabus

SIT Study Abroad

School for International Training

Toll-free 888 272-7881 | Fax 802 258-3296
studyabroad@sit.edu | studyabroad.sit.edu

Climate Modeling and Carbon Management

ENGR 3000 (3 credits / 45 class hours)

SIT Study Abroad Program:

Iceland and Greenland: Climate Change and The Arctic

PLEASE NOTE: This syllabus represents a recent semester. Because courses develop and change over time to take advantage of unique learning opportunities, actual course content varies from semester to semester.

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 proven 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 the Nuuk Institute at Greenland University.

Learning Outcomes

By the end of the seminar, students will be able to:

- Demonstrate knowledge of the conceptual designs of key climate models and their efficiency in climate projections;
- Show awareness of innovative theories and scientific methods to carbon dioxide management;
- Demonstrate knowledge of chemical analyses and ecotoxicology methods used in detecting pollutants in coastal and marine zones;

- Apply scientific methods in the evaluation of weather trends and climate change projections;
- Produce critical and analytical essays on issues of geoengineering and carbon management.

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.

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.

<u>Session 1: Types and Sensitivity of Climate Models</u>

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.

Required Reading:

Drake, John (2014). *Climate Modeling for Scientists & Engineers*. SIAM.

Recommended Reading:

Flato, G., J. Marotzke, B. Abiodun, P. Braconnot, S.C. Chou, W. Collins, P. Cox, F. Driouech, S. Emori, V. Eyring, C. Forest, P. Gleckler, E. Guilyardi, C. Jakob, V. Kattsov, C. Reason and M. Rummukainen, 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* [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. Retrieved from: https://www.ipcc.ch/pdf/assessment-report/ar5/wg1/WG1AR5_Chapter09_FINAL.pdf (Chapter 9.1. Climate Models and Their Characteristics and 9.2. Techniques for Assessing Model performance)

Randall, D.A., R.A. Wood, S. Bony, R. Colman, T. Fichefet, J. Fyfe, V. Kattsov, A. Pitman, J. Shukla, J. Srinivasan, R.J. Stouffer, A. Sumi and K.E. Taylor, 2007: Cilmate Models and Their Evaluation. In *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M.Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. Retrieved from: https://www.ipcc.ch/pdf/assessment-report/ar4/wg1/ar4-wg1-chapter8.pdf (Chapter 8.6. Climate Sensitivity and Feedback).

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.

Required Reading:
Rasch, Philip (Ed.) (2015). *Climate Change Modeling Methodology*. Larkspur, CA: Springer.
How do climate models work? (2012) *Skeptical Science*. Retrieved from: http://www.skepticalscience.com/how-do-climate-models-work.html

Recommended Reading:
Flato, G., J. Marotzke, B. Abiodun, P. Braconnot, S.C. Chou, W. Collins, P. Cox, F. Driouech, S. Emori, V. Eyring, C. Forest, P. Gleckler, E. Guilyardi, C. Jakob, V. Kattsov, C. Reason and M. Rummukainen, 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* [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. Retrieved from: https://www.ipcc.ch/pdf/assessment-report/ar5/wg1/WG1AR5_Chapter09_FINAL.pdf (Chapter 9.2. Techniques for Assessing Model Performance and 9.4. Simulation of Recent and Longer-Term Records in Global Models)

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.

Required Reading:
Climate Model Uncertainty. A Report by the Lighthill Risk network. (2014) Retrieved from: http://www.lighthillrisknetwork.org/uploads/Climate-Model-Uncertainty.pdf

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.

Required Reading:
Integrated Assessment Modeling. Retrieved from: http://www.epa.gov/sustainability/analytics/integrated-assessment.htm
Vuuren, D. P. Van et al. (2009) How well do integrated assessment models simulate climate change? *Climatic Change*. Retrieved from: http://www.climate.unibe.ch/~plattner/papers/vanvuuren09cc_online_first.pdf

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.

Required Reading:

Emmanuel, Rohinton and Baker, Keith (2012). *Carbon Management in the Built Environment*. New York: 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.

Required Reading:

Narbel, Patrick, Hansen, Jan Petter and Lien, Jan R. (2014) *Energy Technologies and Economics*. Switzerland: Springer (Chapter 1: Basic Physical Processes and Economics and Chapter 2: Fossil Energy Systems)

Session 3: Innovation and Carbon Dioxide Management

This session is led by Sandra Snaebjornsdottir (depending on availability), an Icelandic scientist engaged in an innovative experimental project that aims to make gas turn into stone for better storage of carbon dioxide emitted in the air.

Required Reading:

Fountain, Henry (2015).Turning Carbon Dioxide into Rock, and Burying It. In *The New York Times, Feb. 9. 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.

Required 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: Pollution in the Coastal Arctic

This module introduces students to the main chemistry behind contamination and range of pollutant types in the coastal and marine zones. It focuses on the sources and effects of non-radioactive pollutants and persistent organic pollutants (POPs). Students will gain knowledge in the best methods for detecting effects and insight into chemical analyses and ecotoxicology. Particular attention is given to pollutant transport processes and modeling methods.

Session 1: Monitoring Pollutants in Arctic Coastal and Marine Environment

This session reviews case studies that show the accumulation and spread of pollutants in coastal and marine Arctic environments, how these ecosystems are impacted by pollutants, and the effect of these pollutants on climate change in the Arctic. Students will explore methods of monitoring and modeling the accumulation of these pollutants.

Required Reading:

Stone, David (2015) *The Changing Arctic Environment: The Arctic Messenger*. Cambridge: Cambridge University Press

Muir, D. C. G., Wagemann, R., Hargrave, B. T., Thomas, D. J., Peakall, D. B., & Norstrom, R. J. (1992). Arctic marine ecosystem contamination. *Science of the Total Environment, 122*(1), 75-134.

<u>Session 2: Approaches to Simulation of Pollutants in the Arctic</u>

This session looks at simulation models and case studies of pollutants in the Arctic and how they are spread through ocean currents, food chains bioaccumulation, and atmospheric transport. Students will model trends in the transport of pollutants in and throughout the Arctic.

Required Reading:

Brown, T. N., & Wania, F. (2008). Screening chemicals for the potential to be persistent organic pollutants: A case study of Arctic contaminants. *Environmental science & technology*, *42*(14), 5202-5209.

Kelly, B. C., & Gobas, F. A. (2003). An arctic terrestrial food-chain bioaccumulation model for persistent organic pollutants. *Environmental science & technology*, *37*(13), 2966-2974.

<u>Session 3: Arctic Air Pollution and Climate Change</u>

This session explores the origins of air pollution in the Arctic, as well as its impact on climate change and the impact of climate change on the transport of air pollutants to the Arctic.

Required Reading:

Law, Katherine et al. (2014). Arctic Air Pollution: New Insights from POLARCAT-IPY. Retrieved from: http://journals.ametsoc.org/doi/pdf/10.1175/BAMS-D-13-00017.1

<u>Session 4: Impact of Pollutants on Biodiversity and Human Health</u>

This session explores the impact that pollutants in the Arctic have on the health of human communities as well as plant and animal communities. Students will model how Arctic pollutants impact biodiversity in the region and explore policies that attempt to curb the impact of pollution on human health.

Required Reading:

Burek, K. A., Gulland, F. M., & O'Hara, T. M. (2008). Effects of climate change on Arctic marine mammal health. *Ecological Applications*, *18*(sp2), S126-S134.

Ayotte, P., Bruneau, S., & Ve, A. (1995). Arctic air pollution and human health: what effects should be expected?. *Science of the total environment*, *160*, 529-537.

Module 4: Arctic Energy

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

<u>Session 1: Arctic Energy Resources</u>

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.

Required 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 Bjorn Gunnarsson, from the School for Renewable Energy Science in Akureyri, Iceland.

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 in Greenland
This session takes place in Greenland, where students are introduced to sample renewable energy projects and research from Greenland.

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.

Evaluation and Grading Criteria

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

Description of Assignments:

- Review (4 pages): the review should cover at least two of the references of the required predeparture readings.
- Research Paper (6-8 pages): the paper should demonstrate the student's ability to apply scientific methods and critical thinking in engaging with a climate modeling approach or carbon management problem.
- Quizzes: Two in-class quizzes will be used to assess students' knowledge of the theoretical and field-based materials covered in-class lectures and during site visits.
- Participation: Participation will be graded by timely arrival, active involvement in class discussions, and culturally appropriate behavior on excursions.

Assessment:

Review	20%
Thematic paper	40%
Quizzes (2)	30%
Participation	10%

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

Academic Policies: SIT prides itself on providing students with an experientially based program; we hold ourselves, and our students, to the highest of academic standards. Students are asked to refer to the **SIT Study Abroad Handbook** for policies on academic integrity, ethics, academic warning and probation, diversity and disability, sexual harassment and the academic appeals process.

Disability Services: Students with disabilities are encouraged to contact Disability Services at disabilityservices@sit.edu for information and support in facilitating an accessible educational experience. Additional information regarding SIT Disability Services, including a link to the online request form, can be found on the Disability Services website at http://studyabroad.sit.edu/disabilityservices.