DRAFT syllabus
ECS 568S: Integrated Assessment Modeling
Spring 2027
Wed 1:25-3:55 pm

Instructor

Name: Dan Loughlin, PhD, Adjunct Professor
Pronouns: he, him
Email address: Daniel.Loughlin@duke.edu
Office hours: By appointment via Zoom. Please email me to arrange a time; I aim to respond promptly and make myself readily available to students.

Overview and objectives

Are electric vehicles (EVs) good or bad for the environment? How much electricity do data centers use, and how much does it matter how they get it? Are net-zero decarbonization targets achievable, and what barriers remain? Could aggressive biofuel targets increase food prices? How does drought affect energy, crop, and land-use choices? The answers depend on location, assumptions, technologies, policies, and how the future develops. Integrated assessment models (IAMs) simulate the connections and co-evolution of human and Earth systems so we can systematically explore such questions—not as simple predictions, but as outcomes under different assumptions and possible futures.

IAMs are computer models that simulate the dynamics and co-evolution among Earth's energy, buildings, industry, transportation, agriculture, water, and climate systems. IAMs serve as computational laboratories, letting us ask "What if?" questions. Sometimes IAMs provide answers; sometimes they point us in the directions of additional questions we should be asking, fueling an iterative approach to problem solving.

IAMs have now been available for nearly 50 years, evolving as computing and storage improve and as the questions to which they are being applied change. Early applications focused on projecting CO2 global emissions into the future. In the 2000s, IAMs were used to inform international collaborations on climate, such as the Paris Climate Agreement. Today's state-of-the-art IAMs are being used to assess the impacts of new and emerging technologies, develop cost-effective strategies for decarbonization, identify research and development priorities, and explore complex topics at the nexus of energy, climate, land use, and the environment.

The primary objective of this class is to give students hands-on experience using the open-source Global Change Analysis Model (GCAM) to examine the energy, water, air-pollution, and greenhouse-gas implications of emerging energy technologies and policy scenarios (http://jgcri.github.io/gcam-doc/). We will primarily use GCAM-USA, which simulates interacting human and Earth systems through 2100 across 32 global regions and resolves the United States at the state level. For class projects, students may instead use GCAM-China, which includes province-level resolution, or global GCAM, which runs faster because it does not include state- or province-level disaggregation. A secondary objective is to introduce students to modeling and help them determine whether it might be an interesting career path. Students will learn about different types of models, techniques such as sensitivity and uncertainty analysis, and methods for designing and conducting computational experiments. Even if students do not intend to pursue a career in modeling, understanding how models can support decision-making is a valuable skill in a wide range of fields.

GCAM is an "IPCC-class model," having been used in support of numerous global climate-change mitigation planning activities. Being able to use it in a classroom setting is a unique opportunity. That said, GCAM is a complicated model to learn and apply. To address the model's learning curve, students will use the GLIMPSE-CE decision-support software, derived from EPA's GLIMPSE (https://epa.gov/glimpse). GLIMPSE-CE provides an easy-to-use graphical interface for GCAM, facilitating the implementation of policies, development and execution of scenarios, and visualization of results. GLIMPSE-CE allows students to focus more on understanding how GCAM works and on interpreting its results.

By the end of the course, students will be able to explain the structure and uses of integrated assessment models; design policy, technology, sensitivity, and scenario experiments in GCAM; implement and run those experiments using GLIMPSE-CE; analyze energy, water, air-pollution, land-use, and greenhouse-gas outcomes; evaluate model results in light of assumptions and uncertainty; and communicate findings, limitations, and policy-relevant insights through a technical presentation.

Format

*Note from instructor on new class format**:** In previous semesters, GCAM's runtime (~1 hour) limited our ability to perform modeling and analysis in class. The new once-a-week, 2.5-hour format is meant to address that. At the start of many sessions, we'll set up and start the model. While GCAM is running, I'll cover relevant material ("How does GCAM work?", "Developing decarbonization strategies", "Exploring a topic using scenarios"). During the final portion of class, we'll analyze the results together, discuss outcomes, and*

identify follow-up questions, with selected extensions to be completed as homework. The longer class period also provides additional opportunities to learn from guest speakers, with expected topics including the environmental impacts of data centers, the development of state-level climate action plans, and international cooperation on decarbonization. Together, these changes are intended to make class meetings more interactive, applied, and closely connected to the ways integrated assessment modeling is used in professional practice.

This course will meet in person once each week. Sessions will combine lectures with hands-on modeling and analysis activities. Students will complete weekly assignments and an individual or small-group project culminating in a presentation.

A major component of the course is the project. Students will participate in individual or team projects that will culminate with each team presenting its findings. Students are able to choose topics of relevance to their own interests, so long as those investigations are supported by GLIMPSE.

The course project will be developed in stages. Students will identify a research question, define a baseline and one or more comparison scenarios, document key assumptions, run and evaluate the model, and present findings and limitations. Interim milestones, submission requirements, presentation length, and evaluation criteria will be provided in Canvas.

Past projects have included topics such as assessments of:

- North Carolina joining the Regional Greenhouse Gas Initiative
- Rollbacks to many of the key provisions of the Inflation Reduction Act
- Economy-wide vs. sector-specific GHG caps in California
- System-wide and emissions impacts of reduced beef consumption
- Energy and emissions implications of climate-motivated population migration
- Comparative assessment of mitigation options in the US, China, and India
- Impacts of expanded water access in Northern Africa as a result of infrastructure improvements
- Effect of biomass in mitigation schemes on global food prices

For the presentations, we will focus on how to give effective technical presentations, including laying out the problem, approach taken to address it, results, and insights. Particular attention will be given to conciseness, developing a compelling storyline, data presentation, uncertainty, and being straightforward about the study's strengths and limitations.

Required texts

There is no required textbook for this course. All readings will be available online via the Duke library.

More on Instructor

The instructor for this course is Dr. Dan Loughlin. After 22 years with the U.S. Environmental Protection Agency's Office of Research and Development, he founded the Energy and Environmental Modeling Group, through which he continues to develop GLIMPSE-CE and conduct research and GCAM applications. His specialties include energy-system modeling, technology assessment, estimating air-pollutant and greenhouse-gas emissions for technology and policy scenarios, and sensitivity and uncertainty analysis. He has served as an Adjunct Professor with the Nicholas School of the Environment since 2019 and also holds academic appointments at North Carolina State University and the University of North Carolina at Chapel Hill. He has contributed as an author to two National Climate Assessments.

Grading

- 10% - Class participation, including attendance and participation in discussions
- 40% - Homework
- 50% - Team project and presentation

Schedule (subject to change). Current topics and activities are listed below; required preparation, assignment deadlines, project milestones, and any schedule updates will be posted in Canvas. There will be no class on March 10, 2027.

1/6/2027	Introduction to 568S
	Demonstration: GLIMPSE and GCAM applied to assess state-level impacts of EVs
1/13/2027	What is an Integrated Assessment Model?
	Guest speaker on a global GCAM application
1/20/2027	Modeling concepts and taxonomy
	Setting up and running GCAM on Duke virtual computer
1/27/2027	The GCAM model: history and applications
	Simulating a Net Zero strategy
2/3/2027	Modeling policies in GCAM
	Evaluating the role of carbon management in achieving Net Zero
2/10/2027	How does GCAM work?
	Simulating an EV subsidy
2/17/2027	Designing experiments: sensitivity analysis
	Guest presentation on data centers
2/24/2027	Designing experiments: scenario analysis

	In-class scenario development exercise
3/3/2027	Overview of class projects
	Simulating how drought impacts energy, water, land decisions in GCAM
No class	
3/17/2027	Advanced modeling topics: GCAM's data system, XML input file structure, query file
	Time to work on class project
3/24/2027	Guest speaker on America's All-In project
	Time to work on class project
3/31/2027	EMF and inter-model comparison exercises
	Time to work on class project
4/7/2027	Wrap-up and future directions for IAMs
	Time to work on class project
4/14/2027	Final presentations

Assignments

Assignment instructions, due dates, submission procedures, and grading criteria will be posted in Canvas. Unless an assignment states otherwise, students should submit work through Canvas by the posted deadline. Students who anticipate difficulty meeting a deadline should contact the instructor as early as possible to discuss available options.