CEVE 421/521 (Climate Risk Management) Syllabus

Spring 2024

Course Description

Climate variability and change pose threats to lives and livelihoods. These climate risks can be managed through the design and operation of infrastructure systems, as well as through disaster response and recovery. Decisions about how to develop and choose risk management strategies are often based on pure vibes, but occasionally rigorous quantitative analyses that make use of scientific information can inform them (we will focus on these cases). These analyses involve integrating knowledge from multiple disciplines to balance competing goals (objectives) under uncertainty.

In this course, you will learn climate science, uncertainty quantification, and decision analysis methods to support climate risk management. You will be assigned readings for every class that cover both methods and applications, and will work collaboratively to implement key concepts through programming problem sets. Active class participation is required. Methods covered include scenario analysis, exploratory modeling, cost-benefit analysis, single- and multi-objective policy search, reinforcement learning, deep uncertainty, robust decision making, and equitable decision making.

Course Information

Instructor

- James Doss-Gollin
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- Ryon 215

TA

TBD

Meetings

- MWF
- 11-11:50am
- TBD

Prerequisites & Preparation

The following prerequisites are required:

- An introductory course in probability and statistics, such as CEVE 313, is strictly required.

In addition, the following prerequisites are encouraged.

- Some exposure to Python, Julia, Matlab, R, or another programming language
- Additional coursework in applied statistics
- Linear algebra (you should be comfortable with matrix notation and basic operations)
- Optimization (you should be comfortable writing down optimization problems)

If you are unsure whether your background gives you an adequate preparation for this course, *please contact the instructor!*

> What If My Skills Are Rusty?
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> If your programming, mathematics, or statistics skills are a little rusty, don't worry! We will review concepts and build skills over the course of the semester.

Course Objectives

After completing this course, you will be able to:

1. Evaluate and describe the strengths and weaknesses of different approaches to modeling the impact of weather and climate hazards on critical systems.
2. Apply and critique methods for cost-benefit analysis, optimization, policy search, and stochastic control to climate adaptation problems.
3. Describe multiple frameworks for decision making under deep uncertainty.
4. Decision analytical frameworks well suited to a particular problem and justify the choice.

Required Materials

No textbook is required for this course. All materials will be posted as open source on the course website or on Canvas.

You will regularly be assigned scientific papers to read. Where those are available through the Rice library, you will be expected to access them yourself. You are encouraged, though not required, to use Zotero (Rice students have free storage). See Fondren Library's Resources for resources.

You will need a working laptop for this class. If you do not have access to a working laptop, or if you lose access during the semester, please email the instructor.

A Community of Learning

Rice's core values are responsibility, integrity, community, and excellence. Our goal is to create a learning community aligned with these core values.

Core Expectations

Course success involves a dual responsibility on the part of the instructor and the student.

As the instructor, my responsibility is to provide you with a structure and opportunity to learn. To this end, I commit to:

- provide organized and focused lectures, in-class activities, and assignments;
- encourage students to regularly evaluate and provide feedback on the course;
- manage the classroom atmosphere to promote learning;
- schedule sufficient out-of-class contact opportunities, such as office hours;
- allow adequate time for assignment completion;
- make lecture materials, class policies, activities, and assignments accessible to students.

Students are responsible for their own learning in the course and should commit to:

- attending all lectures;
- doing all required preparatory work before class;
- actively participating in online and in-class discussions;
- beginning assignments and other work early; and
- attending office hours as needed.

> **!** What If I'm Sick?
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> Please stay home if you're feeling sick! This is beneficial for both for your own recovery and the health and safety of your classmates. We will also make any necessary arrangements for you to stay on top of the class material and if whatever is going on will negatively impact your grade, for example by causing you to be unable to submit an assignment on time.

Diversity, Equity, and Inclusion

Rice is committed to building and maintaining an equitable and inclusive campus community. Diversity can refer to multiple ways that we identify ourselves, including but not limited to race, color, national origin, language, sex, disability, age, sexual orientation, gender identity, religion, creed, ancestry, belief, veteran status, or genetic information. Each of these diverse identities, along with many others not mentioned here, shape the perspectives our students, faculty, and staff bring to our campus. We, at Rice, will work to promote diversity, equity and inclusion not only because diversity fuels excellence and innovation, but because we want to pursue justice. We acknowledge our imperfections while we also fully commit to the work, inside and outside of our classrooms, of building and sustaining a campus community that increasingly embraces these core values.

Each of us is responsible for creating a safer, more inclusive environment.

Accommodation for Students with Disabilities

If you have a documented disability or other condition that may affect academic performance you should: 1) make sure this documentation is on file with the Disability Resource Center (Allen Center, Room 111 / adarice@rice.edu / x5841) to determine the accommodations you need; and 2) talk with me to discuss your accommodation needs.

Accommodation for Scheduling Conflicts

If any of our class meetings conflict with your religious events, student athletics, or other non-negotiable scheduling conflict, please let me know ASAP so that we can make arrangements for you.

Mask Policies

Masks are welcome but not required in the classroom. However, if a colleague (student, faculty, or staff) requests that others wear a mask, you are *strongly encouraged* to make them feel safe. Please do not ask someone making such a request to disclose their underlying medical condition. If for some reason you need your instructor or classmates to wear a mask, please let me know and I will communicate this to the class without disclosing your identity.

These policies may change over the course of the semester as the situation evolves.

Academic Integrity

This class is designed to encourage collaboration, and students are encouraged to discuss their work with other students. Engineering as a profession relies upon the honesty and integrity of its practitioners (see *e.g.* the American Society for Civil Engineers' Code of Ethics). **All work submitted must represent the students' own work and understanding**, whether individually or as a group (depending on the particulars of the assignment).

If you are ever unclear about academic integrity, please ask! Additionally, always err on the side of providing more information.)

Rice Honor Code

More specifically, all students will be held to the standards of the Rice Honor Code, a code that you pledged to honor when you matriculated at this institution. If you are unfamiliar with the details of this code and how it is administered, you should consult the Honor System Handbook at honor.rice.edu/honor-system-handbook/. This handbook outlines the University's expectations for the integrity of your academic work, the procedures for resolving alleged violations of those expectations, and the rights and responsibilities of students and faculty members throughout the process.

AI/ML Resource Policy

Large language models (LLMs), like GPT, are powerful tools for generating text that can be used for coding and doing data analysis. This is at once empowering (LLMs are powerful and can save you time) and risky (LLMs can make mistakes that are hard to detect).

Our general view is that LLMs are powerful tools that you will encounter and use when you leave this classroom, so it's important to learn how to use them responsibly and effectively. You are generally permitted to use LLMs in this course, but ultimately, you are responsible for guaranteeing, understanding, and interpreting your results. In particular:

- One of the best applications of LLMs is to write code. This can help accelerate your workflow, especially when you are learning new syntax. However, LLMs can make bad decisions about how to structure your code, can introduce bugs, and can mislead you about what your code is doing. You are responsible for understanding and debugging your code, and for ensuring that it does what you intend it to do.

- LLMs should not be used to generate text that you submit as your own work. If you are assigned a writing assignment, the point is to stimulate your thought process, and you short-cut this if you ask a LLM to generate the response for you. This leads to shallow thinking! However, you *may* use tools including LLMs (but also Grammarly, spell-check, etc.) to help you edit your writing. This can sometimes be a fine line; it's always better to ask if you're not sure, and to disclose your use of these tools in your submission

The resources page has links to helpful ideas about LLMs and how to use them.

Policy on Web Posting of Course Materials

Uploading course materials to web sites is not an authorized use of the course material. Both the poster and the user are in violation of the university policy, which is actionable.

Grading

Your final grade will be calculated as follow:

Category	Points (421)	Points (521)
Reading quizzes	10	10
Labs	10	10
Tests	40	30
Project	40	40
Reading Discussion	0	10

Reading Quizzes

The purpose of assigning readings is to enhance class discussions. Students who are prepared for class enhance the learning experience for everyone and enable a collaborative group discussion. At the start of classes for which reading was assigned, expect a very short (5 minute) quiz covering basic concepts from the reading. You should be able to get all points on these readings if you have done the reading, even if you found key concepts challenging or confusing.

Your lowest two reading quizzes will be dropped.

Labs

On Fridays we will use class time for hands-on programming exercises ("labs") to give you guided practice applying the concepts and methods from class. These labs will be announced on the course website ahead of time so anyone who is able can bring a laptop to class. These labs can be done in groups; if you cannot bring a laptop to class for whatever reason, you will be able to (and are encouraged to) work with other students, though you must turn in your own assignment for grading. All labs will cover either a set of programming tools or a case study.

Your lowest two labs will be dropped.

Tests

In-class written exams will be given for each module of the course. Tests are designed to be straightforward and will cover key ideas from reading, as well as key terms and concepts from lecture and code interpretation related to labs.

Project

We will build a case study related to house elevation over the course of the semester through weekly labs. Answers will be posted for each lab, so mistakes made in one lab do not pass to the next.

For a final project, you will be asked to incorporate at least two approaches from the course into the case study. For example, you might improve the representation of additional sources of uncertainty, use a more sophisticated optimization algorithm, or change the objectives of the optimization problem.

Reading Discussion

All students enrolled in the 521 section (i.e., graduate students) will present one of the papers assigned to the class and lead a discussion. This discussion should take 30-50 minutes. You will be graded on the quality of your presentation, the depth of your understanding of the reading, and your ability to lead a discussion. You should sign up for a time by the second week of class. You should meet with your instructor at least one week before your presentation to discuss the reading and your discussion plan.

Students enrolled in the 421 section may choose to present a paper alone or in a group. If you choose to present a paper, you will be graded on the same scale as the 521 students.

Late Work Policy

- Late projects will be subjected to a 10% penalty per day. Specifically, your grade will be multiplied 0.9^d where d is the number of days late.
- Late labs will not be accepted, because we will discuss solutions in class.

As described above, your lowest two labs and reading quizzes will be dropped. This is intended to accommodate events like minor illnesses, travel to a conference, and other circumstances that may cause you to miss a lab or quiz. If a major circumstance arises (e.g., a death in the family, a serious illness, etc.) that causes you to miss an extended period of time, please contact the instructor to discuss accommodations.

Preliminary Schedule

The following schedule outlines our planned topics and readings for the semester. All assignments will be posted on Canvas.

> **Note**
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> Not all readings listed here will be assigned in full. Some may be assigned as optional reading and others may be assigned as excerpts.

Week	Course Dates	Topic	Reading	Lab
	Module 1:	**Introduction**		
1	1/8, 1/10, 1/12	Introduction to climate risk management	Frank (2022), Loucks (2017) Ch. 1	Software installation
2	1/17, 1/19	Science of climate hazard	Seneviratne et al. (2021), Lall et al. (2018)	Julia basics
3	1/22, 1/24, 1/26	Vulnerability, exposure, and impacts	Wing et al. (2020), Bonnafous et al. (2017)	DataFrames, Distributions
4	1/29, 1/31, 2/2	Systems	Reed et al. (2022),	*No lab (test 1)*
	Module 2:	**Decision Analysis**		
5	2/5, 2/7, 2/8	Cost-benefit analysis	Arrow et al. (2013)	House Elevation Case Study
6	2/12, 2/14, 2/16	Scenario analysis	Bankes (1993)	BRICK
7	2/19, 2/21, 2/23	Policy search and optimization	van Berchum et al. (2019), Schwetschenau et al. (2023)	Metaheuristics
8	2/26, 2/28, 3/1	Multiobjective policy search	Zarekarizi et al. (2020)	BlackBoxOptim
9	3/4, 3/6, 3/8	Sequential decision problems	Herman et al. (2020), Quinn et al. (2017), Fletcher et al. (2019), Sutton & Barto (2018)	Case Study: The Parking Garage
10	3/18, 3/20, 3/22	Deep uncertainty	Schneider (2002), Lempert & Schlesinger (2000), Oreskes et al. (1994)	*No lab (test 2)*
	Module 3:	**Thinking Critically**		
11	3/25, 3/27, 3/29	Robustness	Herman et al. (2015), McPhail et al. (2019)	Case Study: The Lake Problem
12	4/1, 4/3, 4/5	Equity and justice	Pollack et al. (2023), Fletcher et al. (2022)	*No lab (project workshop)*
13	4/10, 4/12	Financial and systemic risks	Thomson et al. (2023), Condon (2021)	*No lab (project workshop)*
14	4/15, 4/17, 4/19	Reflections	Keller et al. (2021), Gilligan & Vandenbergh (2020)	*No lab (test 3)*

Arrow, K., Cropper, M., Gollier, C., Groom, B., Heal, G., Newell, R., et al. (2013). Determining benefits and costs for future generations. *Science*, *341*(6144), 349–350. https://doi.org/10.1126/science.1235665

Bankes, S. (1993). Exploratory modeling for policy analysis. *Operations Research*, *41*(3), 435–449. https://doi.org/c7rgcr

Bonnafous, L., Lall, U., & Siegel, J. (2017). A water risk index for portfolio exposure to climatic extremes: Conceptualization and an application to the mining industry. *Hydrology and Earth System Sciences*, *21*(4), 2075–2106. https://doi.org/f96k67

Condon, M. (2021). Market myopia's climate bubble. https://doi.org/10.2139/ssrn.3782675

Fletcher, S., Lickley, M., & Strzepek, K. (2019). Learning about climate change uncertainty enables flexible water infrastructure planning. *Nature Communications*, *10*(1), 1782. https://doi.org/10.1038/s41467-019-09677-x

Fletcher, S., Hadjimichael, A., Quinn, J., Osman, K., Giuliani, M., Gold, D., et al. (2022). Equity in Water Resources Planning: A Path Forward for Decision Support Modelers. *Journal of Water Resources Planning and Management*, *148*(7), 02522005. https://doi.org/10.1061/(ASCE)WR.1943-5452.0001573

Frank, T. (2022, August 22). Bold New Jersey Shore Flood Rules Could Be Blueprint for Entire U.S. Coast. *Scientific American*. Retrieved from https://www.scientificamerican.com/article/bold-new-jersey-shore-flood-rules-could-be-blueprint-for-entire-u-s-coast/

Gilligan, J. M., & Vandenbergh, M. P. (2020). Beyond wickedness: Managing complex systems and climate change. *Vanderbilt Law Review*, *73*, 1777–1810. Retrieved from https://wp0.vanderbilt.edu/lawreview/2020/12/beyond-wickedness-managing-complex-systems-and-climate-change/

Herman, J. D., Reed, P. M., Zeff, H. B., & Characklis, G. W. (2015). How should robustness be defined for water systems planning under change? *Journal of Water Resources Planning and Management*, *141*(10), 04015012. https://doi.org/10.1061/(asce)wr.1943-5452.0000509

Herman, J. D., Quinn, J. D., Steinschneider, S., Giuliani, M., & Fletcher, S. (2020). Climate adaptation as a control problem: Review and perspectives on dynamic water resources planning under uncertainty. *Water Resources Research*, e24389. https://doi.org/10.1029/2019wr025502

Keller, K., Helgeson, C., & Srikrishnan, V. (2021). Climate risk management. *Annual Review of Earth and Planetary Sciences*, *49*(1), 95–116. https://doi.org/10.1146/annurev-earth-080320-055847

Lall, U., Johnson, T., Colohan, P., Aghakouchak, A., Arumugam, S., Brown, C., et al. (2018). Chapter 3: Water. In D. R. Reidmiller, D. R. Easterling, K. E. Kunkel, K. L. M. Lewis, T. K. Maycock, & B. C. Stewart, *Impacts, Risks, and Adaptation in the United States: The Fourth National Climate Assessment, Volume II*. Washington, D.C.: U.S. Global Change Research Program. https://doi.org/10.7930/NCA4.2018.CH3

Lempert, R. J., & Schlesinger, M. E. (2000). Robust strategies for abating climate change. *Climatic Change*, *45*(3-4), 387–401. https://doi.org/10.1023/A:1005698407365

Loucks, D. P. (2017). *Water resource systems planning and management: An introduction to methods, models, and applications*. Cham: Imprint: Springer.

McPhail, C., Maier, H. R., Kwakkel, J. H., Giuliani, M., Castelletti, A., & Westra, S. (2019). Robustness metrics: How are they calculated, when should they be used and why do they give different results? *Earth's Future*, 169–191. https://doi.org/10.1002/2017ef000649

Oreskes, N., Shrader-Frechette, K., & Belitz, K. (1994). Verification, validation, and confirmation of numerical models in the Earth sciences. *Science*. https://doi.org/10.1126/science.263.5147.641

Pollack, A., Helgeson, C., Kousky, C., & Keller, K. (2023, September 15). Transparency on underlying values is needed for useful equity measurements. https://doi.org/10.31219/osf.io/kvyxr

Quinn, J. D., Reed, P. M., & Keller, K. (2017). Direct policy search for robust multi-objective management of deeply uncertain socio-ecological tipping points. *Environmental Modelling & Software*, *92*, 125–141. https://doi.org/10.1016/j.envsoft.2017.02.017

Reed, P. M., Hadjimichael, A., Moss, R. H., Brelsford, C., Burleyson, C. D., Cohen, S., et al. (2022). Multisector Dynamics: Advancing the Science of Complex Adaptive Human-Earth Systems. *Earth's Future*, *10*(3), e2021EF002621. https://doi.org/10.1029/2021EF002621

Schneider, S. H. (2002). Can we estimate the likelihood of climatic changes at 2100? *Climatic Change*, *52*(4), 441–451. https://doi.org/http://dx.doi.org/10.1023/A:1014276210717

Schwetschenau, S. E., Kovankaya, Y., Elliott, M. A., Allaire, M., White, K. D., & Lall, U. (2023). Optimizing Scale for Decentralized Wastewater Treatment: A Tool to Address Failing Wastewater Infrastructure in the United States. *ACS ES&T Engineering*, *3*(1), 1–14. https://doi.org/10.1021/acsestengg.2c00188

Seneviratne, S. I., Zhang, X., Adnan, M., Badi, W., Dereczynski, C., Di Luca, A., et al. (2021). Weather and climate extreme events in a changing climate. In V. Masson-Delmotte, P. Zhai, A. Pirani, S. L. Connors, C. Péan, S. Berger, et al. (Eds.), *Climate change 2021: The physical science basis. Contribution of working group I to the sixth assessment report of the intergovernmental panel on climate change*. Book section, Cambridge, UK and New York, NY, USA: Cambridge University Press. https://doi.org/10.1017/9781009157896.013

Sutton, R. S., & Barto, A. G. (2018). *Reinforcement learning: An Introduction* (Second Edition). Cambridge, Massachusetts and London, England: MIT Press.

Thomson, H., Zeff, H. B., Kleiman, R., Sebastian, A., & Characklis, G. W. (2023). Systemic Financial Risk Arising From Residential Flood Losses. *Earth's Future*, *11*(4), e2022EF003206. https://doi.org/10.1029/2022EF003206

van Berchum, E. C., Mobley, W., Jonkman, S. N., Timmermans, J. S., Kwakkel, J. H., & Brody, S. D. (2019). Evaluation of flood risk reduction strategies through combinations of interventions. *Journal of Flood Risk Management*, *12*(S2), e12506. https://doi.org/10.1111/jfr3.12506

Wing, O. E. J., Pinter, N., Bates, P. D., & Kousky, C. (2020). New insights into US flood vulnerability revealed from flood insurance big data. *Nature Communications*, *11*(1, 1), 1444. https://doi.org/10.1038/s41467-020-15264-2

Zarekarizi, M., Srikrishnan, V., & Keller, K. (2020). Neglecting uncertainties biases house-elevation decisions to manage riverine flood risks. *Nature Communications*, *11*(1, 1), 5361. https://doi.org/10.1038/s41467-020-19188-9