Department of Geography and Environmental Studies

GEOG5001: Modelling Environmental Systems

Fall 2026

Instructor: Murray Richardson
Phone: (613) 520-2600 x2574
Email: murrayrichardson@cunet.carleton.ca
Office Hours: Drop-in or by appointment
Meetings: Tuesdays and Thursdays 10:05 a.m. to 11:25 a.m.
Brightspace Page: https://brightspace.carleton.ca/d2l/home/453323

INTRODUCTION

Calendar description: Methods and problems of research on the physical environment, with illustrative material taken from the atmospheric and earth sciences. Issues such as the identification and behaviour of environmental systems, temporal and spatial scale, experimental method under field conditions, and simulation and model development are considered.

Summary/Objectives: This course aims to provide students beginning their MSc program (or those entering a PhD if interested) with a structured overview of environmental modelling with application to physical geography and the environmental sciences. The course focuses students' efforts on identifying potential thesis research topics and methods early in their graduate program. It provides an overview of a range of modelling approaches and data analysis methods (and their limitations) commonly used in the environmental sciences. We will meet twice a week, typically alternating between a seminar format, when we will focus on readings and discussions, and a workshop format to develop your skills in empirical environmental modelling.

LEARNING OUTCOMES

By the end of this course, successful students will be able to:

1. Differentiate among the various environmental modelling approaches used in physical geography and environmental science, and understand/explain their different purposes, strengths and weaknesses.
2. Synthesise and actively discuss key arguments, findings and themes within journal articles from physical geography and environmental sciences.
3. Think critically and convey your ideas through scientific writing and oral presentations, at a level that is appropriate for an entry-level research position.
4. Use the R programming language for data manipulation, descriptive statistics, inferential statistics, model fitting and model evaluation, at a level that is appropriate for graduate research in physical geography.
5. Formulate and justify a geographic research question that can be addressed using an environmental modelling approach, implement the steps required to answer the question, and document the analysis and results in a formal scientific report.

READINGS

Required Textbooks:

Harris, R., and Jarvis, C. 2011. *Statistics for Geography and Environmental Science*.
(There will be one copy of this book available on reserve at the library under GEOG5001)

Schimel, Joshua. *Writing science: how to write papers that get cited and proposals that get funded*. OUP USA, 2012. (Available digitally through Carleton University Library)

Douglas, A., Roos, D., Mancini, F., Couto, A., and Lusseau, D. 2024. *An Introduction to R (intro2r.com)*. (Free digital book to help you with R programming and problem sets).

Seminar Resources (Articles and Book Chapters or Other):

A preliminary list of our seminar readings is provided below. These will form the basis of our biweekly seminar discussions and writing assignment topics. A Zotero library will be shared with students containing these bibliographic entries.

Seminar 1: The Structure of Arguments

Oreskes, Naomi, Kristin Shrader-Frechette, and Kenneth Belitz. "Verification, validation, and confirmation of numerical models in the earth sciences." Science 263, no. 5147 (1994)

Kirchner, J. W. Getting the right answers for the right reasons: Linking measurements, analyses, and models to advance the science of hydrology: Water Resour. Res. 42, (2006).

Additionally, in preparation for this seminar, please complete the first two modules of the free "Structure and Function of Arguments" Harvard University online course. Complete up to the end of the second module, "The Reason Rule". Please allot approximately 3 hours to complete this and be sure to complete the quizzes throughout so that you are prepared for our meeting.

Structure and Function of Argument: Introduction to Critical Thinking | Harvard Online

Seminar 2: On Models and Modelling

Adams, Henry D., A. Park Williams, Chonggang Xu, Sara A. Rauscher, Xiaoyan Jiang, and Nate G. McDowell. "Empirical and process-based approaches to climate-induced forest mortality models." Frontiers in plant science 4 (2013).

Burt, W. General/particular, [in:] Castries N., Rogers A., Sherman D.,(eds.) Questioning Geography. Fundamental Debates. (2005).

Demeritt, D. & Wainwright, J. Models, modelling, and geography. Questioning Geography. Oxford: Blackwell 206–25 (2005).

Guo, Mingyang, Qianlai Zhuang, Huaxia Yao, Malgorzata Golub, L. Ruby Leung, Don Pierson, and Zeli Tan. "Validation and sensitivity analysis of a 1-D lake model across global lakes." Journal of Geophysical Research: Atmospheres 126, no. 4 (2021).

Seminar 3: Environmental Systems and Feedbacks

Chapin, F. S. et al. Arctic and boreal ecosystems of western North America as components of the climate system. Global Change Biology 6, 211–223 (2000).

Chorley, Richard & Kennedy, Barbara. Physical Geography: a systems approach (1971).

Davidson, E. A. & Janssens, I. A. Temperature sensitivity of soil carbon decomposition and feedbacks to climate change. Nature 440, 165–173 (2006).

Fewster, R. E. et al. Imminent loss of climate space for permafrost peatlands in Europe and Western Siberia. Nature Climate Change 12, 373–379 (2022).

Seminar 4: Model Complexity and Model Selection

Arismendi, I., Safeeq, M., Dunham, J. B. & Johnson, S. L. Can air temperature be used to project influences of climate change on stream temperature? Environmental Research Letters 9, 084015 (2014).

Hrachowitz, M., Soulsby, C., Imholt, C., Malcolm, I. A. & Tetzlaff, D. Thermal regimes in a large upland salmon river: a simple model to identify the influence of landscape controls and climate change on maximum temperatures. Hydrol. Process. 24, 3374–3391 (2010).

Qiu, H., Hamilton, S. K. & Phanikumar, M. S. Modeling the effects of vegetation on stream temperature dynamics in a large, mixed land cover watershed in the Great Lakes region. Journal of Hydrology 581 (2020).

Weierbach, Helen, Aranildo R. Lima, Jared D. Willard, Valerie C. Hendrix, Danielle S. Christianson, Michaelle Lubich, and Charuleka Varadharajan. Stream temperature predictions for river basin management in the Pacific Northwest and mid-Atlantic regions using machine learning. Water 14.7 (2022)

Seminar 5: Topic and Readings TBD

EVALUATION

Assessment in this course follows a hybrid alternative grading system that combines *standards-based assessment* with *specifications grading*. Within this framework, you will be evaluated on the following coursework:

- Writing Assignments (4)
- Data Modelling Exercises (5)
- Online stats quizzes (5)
- In-person stats quiz (1)
- Journal Article Critique (1)
- Data Modelling Project (1)
- Presentations (3)
- Participation and Engagement

Writing assignments, presentations, the final project and your participation and seminar engagement are assessed using performance standards outlined in rubrics, rather than points. This is a standards-based method, whereby your work will be evaluated at one of four levels: ‘Beginning’, ‘Developing’, ‘Accomplished’, or ‘Mastered’ (‘Success’ or ‘NA’ for participation and engagement) based on clearly defined criteria that you will find in the rubrics for each assessment. Problem sets and your in-person quiz are assessed using traditional

numerical scores because they evaluate specific knowledge and problem-solving skills that are readily measured quantitatively.

In specification grading, final course grades are not determined by averaging scores across all assessments. Instead, final letter grades are associated with bundles of completed work and demonstrated levels of achievement. Performance levels achieved on writing assignments, presentations, the final project and seminar participation/engagement are combined with the letter grades achieved on quizzes and problem sets to determine the final course grade. Higher course grades require students to consistently demonstrate 'Accomplished' or 'Mastered' performance on major assignments while successfully completing the requirements associated with a particular grade bundle (Table 1). This approach emphasizes demonstrated learning, encourages revision and improvement, and rewards sustained achievement over simple point accumulation. Other than an F, the available grade outcomes range from B+ to A+. This reflects the expectation that students entering an MSc program in Geography are prepared to perform at a high level. Performance below the B+ level would suggest that additional preparation may be needed to support success in graduate-level studies in the Department of Geography and Environmental Studies.

Tokens

Each student will start the class with 2 virtual "tokens," which you may spend as follows.

7-day extension on any written assignment or problem set	1 Token
Revision and resubmission of any written assignment, excluding the final project.	1 Token. Revisions are due one week after you receive my feedback.

Token use will be tracked as "Tokens Available" in the grade book on Brightspace alongside your other grades.

Near miss policy:

If you miss a performance standard in a single assessment group by a single level, your final grade will be bumped to the higher level. For example, if you miss achieving an A+ in the course because two of your writing assignments were 'Mastered' and two were 'Accomplished' (instead of 3 'Mastered' and 1 'Accomplished'), and all other specifications were met for the A+ course grade, then your final grade will be bumped to an A+. Here is another example: if you are in the A+ category across all assessment groups except you get an A instead of an A+ on the in-person quiz, your course grade would also be bumped to A+. However, if you received an A- on the quiz, your grade would not be bumped up because that is missing the performance standard by more than 1 level.

Participation and Seminar Engagement: I expect all students to come to class prepared and to participate fully in seminar activities and engage effectively in all discussions. There are separate rubrics provided to evaluate you on these expectations. Participation is evaluated as Success/NA: you either attended regularly, arrived on time and participated in the activities/discussion, or not. Evaluation of seminar engagement evaluation is also binary (Success or NA) and structured to set a bar for students in the A+ and A categories. The following things will be used to assess your seminar engagement: (1) Preparation; (2) Ideas, Analysis and Inquiry; (3) Listening/Responding; and (4) Learning and self-awareness. Please refer to the rubrics for more details.

Table 1 Specification grading table used to determine your final grade in GEOG5001 based on your achievements across all assessments.

	Final Grade				
Assessment	**A+**	**A**	**A-**	**B+**	**F**
Writing Assignments (up to 5)	3 mastered and ≥ 1 accomplished *and* assessed submissions must include the Journal Article Critique	2 mastered and ≥ 2 accomplished or higher *and* assessed submissions must include the Journal Article Critique	≥3 accomplished or higher *and* ≥ 1 developing or higher *and* assessed submissions must include the Journal Article Critique	≥2 accomplished or higher *and* ≥ 2 developing or higher *and* assessed submissions must include the Journal Article Critique	< 2 accomplished
Problem Sets 1-4	Average of 4 problem sets ≥ 90%	Average of 4 problem sets ≥ 85%	Average of 4 problem sets ≥ 80%	Average of 4 problem sets ≥ 77%	Average of 4 problem sets < 77%
Online Quizzes 1-5	5 complete	≥4 complete	≥3 complete	≥3 complete	≤2 complete
In-Person Quiz	A+ (90-100%) or higher	A (85-89%) or higher	A- (80%-84%) or higher	B+ (77-79%) or higher	≤C+
Presentations 1-3	3 complete and ≥2 mastered	3 complete and ≥1 mastered	3 complete and ≥ 2 accomplished or higher	3 complete and ≥ 1 accomplished or higher	0 accomplished
Project	mastered	accomplished or higher	accomplished or higher	developing or higher	beginning or incomplete
Participation	Success	Success	Success	Success	NA
Seminar Engagement	Success	Success	NA	NA	NA

Final Grade Approval: Standing in a course is determined by the course instructor, subject to the approval of the Faculty Dean. This means that grades submitted by the instructor may be subject to revision.

ACADEMIC ACCOMMODATION

Carleton is committed to providing academic accessibility for all individuals. You may need special arrangements to meet your academic obligations during the term. The accommodation request processes, including information about the Academic Consideration Policy for Students in Medical and Other Extenuating Circumstances, are outlined on the Academic Accommodations website (https://students.carleton.ca/course-outline).

You may need special arrangements to meet your academic obligations during the term. For an accommodation request the processes are as follows:

Informal accommodation due to short-term incapacitation: Please discuss short-term accommodation needs with me directly and as at the earliest possible time.

ACADEMIC INTEGRITY

a) Permissibility of submitting substantially the same piece of work more than once for academic credit

If you would like to use any aspect of previous work you have completed in other previous courses or work positions towards your assignments in this class, you must discuss with the instructor ahead of time to obtain permission.

b) Permissibility of group or collaborative work

There is minimal group work in this course. You are encouraged to discuss the course material with each other to brainstorm and share ideas, and to provide peer evaluation. Beyond this, all work submitted must clearly be your own and work that appears in duplication between two or more students will be treated as a case of plagiarism for all students involved.

c) Statement on Plagiarism

The University Academic Integrity Policy defines plagiarism as 'presenting, whether intentionally or not, the ideas, expression of ideas or work of others as one's own.' This includes reproducing or paraphrasing portions of someone else's published or unpublished material, regardless of the source, and presenting these as one's own without proper citation or reference to the original source. Examples of sources from which the ideas, expressions of ideas or works of others may be drawn from include but are not limited to books, articles, papers, literary compositions and phrases, performance compositions, chemical compounds, artworks, laboratory reports, research results, calculations and the results of calculations, diagrams, constructions, computer reports, computer code/software, material on the internet and/or conversations.

Examples of plagiarism include, but are not limited to:

- any submission prepared in whole or in part, by someone else, including the unauthorized use of generative AI tools as described in the course AI use policy
- using ideas or direct, verbatim quotations, paraphrased material, algorithms, formulae, scientific or mathematical concepts, or ideas without appropriate acknowledgment in any academic assignment
- using another's data or research findings without appropriate acknowledgement
- submitting a computer program developed in whole or in part by someone else, with or without modifications, as one's own
- failing to acknowledge sources with proper citations when using another's work and/or failing to use quotations marks.

Plagiarism is a serious offence that cannot be resolved directly by the course's instructor. The Associate Dean of the Faculty follows a rigorous process for academic integrity allegations, including reviewing documents and interviewing the student, when an instructor suspects a

violation has been committed. Penalties for violations may include a final grade of "F" for the course.

For more information on how to cite sources, refer to the library web page "*Citing Your Sources*", available at http://www.library.carleton.ca/help/citing-your-sources.

AI USE POLICY (GEOG5001)

In this course, AI is treated as a supportive collaborator, not a substitute for critical thinking or scholarly integrity. Students are encouraged to use AI tools to enhance their learning, deepen their understanding of course concepts and scientific literature, and streamline technical tasks while emphasizing the importance of original thought and scholarly integrity. Since AI is relatively new and evolving rapidly, we will also use this course to explore and discuss our collective experiences in using AI as a collaborator in research and learning.

Permitted Uses of AI

• Literature Searches, Explorations and Understanding

- Use tools such as Elicit, Notebook LM, ResearchRabbit, or Connected Papers to locate, summarise, and synthesise scientific literature and web sources. AI may help identify key themes, generate summaries for you to read, and organize references. However, students must critically evaluate all AI-generated outputs and be prepared to justify their selection of sources, explain how they interpreted the material, and demonstrate a clear understanding of the content beyond what the AI tool provided. You are solely responsible for ensuring that all sourced content in your academic writing is an accurate reflection of the underlying sources and that those sources are legitimate/real.

• Writing Support

- AI tools such as ChatGPT, Microsoft Copilot and Notebook LM may be used to support academic writing for this course in the following ways:

  1. Generating initial outlines for papers or presentations in response to your own ideas and prompts supplied to the tool.
  2. Refining written work, including clarifying, condensing, and enhancing specific sections through advanced editing suggestions as well as spelling and grammar checking. However, these tools must be used to enhance - not replace - your original thinking. You are expected to write the initial drafts yourself, and AI-generated content should never substitute for your own analysis or argumentation. You must remain the author of your work and be able to explain, defend, and take full responsibility for all content submitted.
  3. Assisting with routine formatting and editorial tasks, such as checking references for consistency, identifying duplication, and improving structural formatting.

- Please beware that many free AI tools may use your inputs to further train the underlying models; If you are worried about submitting and exposing your own IP (e.g. since you may wish to publish your thesis work in the future) then there is a legitimate case to avoid such tools. Using Microsoft Copilot, logged in with your MC1 credentials, will ensure that your inputs are not used to train any models.

• Coding Assistance

- AI tools may be used to assist with R programming, including syntax help, debugging, and code optimization/formatting. Students must ensure they understand the code and can interpret the results of their analyses independently. You should be ready and able to explain any line of code you submit as part of your work for this class an inability to do so may result in a grade of zero for the specific question or assignment.

• Creative Content Generation

- AI may be used to generate explanatory graphics and design presentation slides, and to *help* you generate scientific figures/data visualizations. You are responsible for ensuring that all generated outputs are relevant and accurate. For scientific figures/data visualizations, you may use AI to help generate the code to create the figure from your data sources. However, the figures themselves cannot be generated by directly providing the data to the AI tool. Therefore, if asked, you must be able to supply the code used to generate any scientific figures/data visualizations.

• Tutoring (especially for coding)

- You may find it helpful to use AI as a way to learn and practice certain skills such as R coding (e.g. "Help me practice basic R syntax for working with environmental data", or "Give a brief tutorial on tidyverse syntax in R for someone who already knows basic R syntax, including code comparisons and identifying the advantages of tidyverse syntax wherever possible" or "Help my understand how to interpret the results of a PCA implemented using the psych package in R".

Documentation Requirements

To maintain transparency and academic integrity in relation to AI use, students must:

• Clearly document AI usage in all submitted work. E.g. "An outline was generated with ChatGPT based on my research notes"; "Code generation and debugging was assisted by Copilot." *See also the example at the end of this AI use policy.
• Critically evaluate and revise any AI-generated content to ensure originality, precision of wording and accuracy of information.
• Avoid over-reliance: AI should enhance—not replace—student learning, analysis, and creativity.

Prohibited Uses

• AI-generated first drafts of complete (or major sections of) essays, reports or presentation scripts.
• Using AI to bypass understanding of core concepts, especially in coding or statistical modelling.
• Presenting AI-generated summaries or interpretations without personal insight or evaluation.
• Presenting any AI-generated content as though it is your original thought/analysis/research.

Handling of missing or ambiguous source attributions

Cases of ambiguous, incorrect or missing source attributions in submitted work will be handled in one of the following two ways:

• Oral Evaluation: The student may be required to participate in an oral evaluation to demonstrate their understanding of the source content used for the assignment

- Formal Academic Integrity Review: The case may be referred for formal review under Carleton's Academic Integrity Policy. This process may involve documentation, investigation, and potential academic consequences as outlined by university regulations. Please see the "Academic Integrity" section for more details.

Students are expected to take full intellectual ownership of their work and be able to defend their choices, interpretations, and arguments - regardless of whether AI tools were used in the process.

Rationale

This policy is designed to help students develop critical thinking and research literacy in the age of AI. It encourages effective collaboration with AI tools while maintaining academic rigour. By using AI to enhance literature searches and analysis, consolidate complex information, facilitate coding, and streamline other routine tasks, students can focus on higher-order learning such as interpretation, synthesis, critiquing and evaluation, especially in support of research.

*Note: I used Microsoft Copilot to assist with refining the language, structure, and clarity of this policy, which was adapted from Carleton University's sample policies: Sample Syllabus Statements for AI Use in Courses - Artificial Intelligence. All substantive ideas, examples, and decisions reflect my own judgment. Copilot's role was editorial, and I have reviewed and edited all AI-assisted content to ensure it aligns with my intent.

STATEMENT ON STUDENT MENTAL HEALTH

As a student you may experience a range of mental health challenges that significantly impact your academic success and overall well-being. If you need help, please speak to someone. There are numerous resources available both on- and off-campus to support you. For more information, please consult https://wellness.carleton.ca/.

Emergency Resources (on and off campus): https://carleton.ca/health/emergencies-and-crisis/emergency-numbers/

Carleton Resources:

Emergency Resources (on and off campus)

- Crisis/Urgent Counselling Support: 613-520-6674 (Mon-Fri, 8:30-4:30)
- Suicide Crisis Helpline: call or text 9-8-8, 24 hours a day, 7 days a week.
- For immediate danger or urgent medical support: call 9-1-1

Carleton Resources

- Mental Health and Wellbeing: https://carleton.ca/wellness/
- Health & Counselling Services: https://carleton.ca/health/
- Paul Menton Centre: https://carleton.ca/pmc/
- Academic Advising Centre (AAC): https://carleton.ca/academicadvising/
- Centre for Student Academic Support (CSAS): https://carleton.ca/csas/
- Equity & Inclusivity Communities: https://carleton.ca/equity/

Off Campus Resources

- Distress Centre of Ottawa and Region: call 613-238-3311, text 343-306-5550, or connect
- online at https://www.dcottawa.on.ca
- Mental Health Crisis Service: call 613-722-6914 or toll-free 1-866-996-0991, or connect online at http://www.crisisline.ca
- Good2Talk: call 1-866-925-5454 or connect online at https://good2talk.ca
- The Walk-In Counselling Clinic: for online or on-site service https://walkincounselling.com

Course Schedule

Week/Week of	Tuesday Meeting	Thursday Meeting
1 – Sep 7	No classes on Tuesday	Course Introduction
2 – Sep 14	R Workshop: Intro to R and **Problem Set 1**	**Seminar 1:** The structure of arguments
3 – Sep 21	R Workshop: Central Limit Theorem and Hypothesis Testing **Problem Set 2 (due in two weeks)**	**Seminar 2:** On models and modelling
4 – Sep 28	R Workshop: Power analysis with R workshop and **Problem Set 3 (due in three weeks)**	Writing workshop 1 **Seminar 2 Writing Assignment due today*
5 – Oct 5	**Seminar 3:** Environmental Systems Identification	Murray away for research; no class today
6 – Oct 12	R Workshop: Correlation and Regression	Writing Workshop 2 **Seminar 3 Writing Assignment due today*
7 – Oct 19	R Workshop: CART, MLR, *relaimpo* package in R for MLR; **Problem Set 4**	**Seminar 4:** Model complexity and model selection
Oct 26	Reading Week	
8 – Nov 2	Journal Article Critique Lightning Presentations (5 mins) with Peer Evaluations	R Workshop: Cross-validation, CART, Random Forest in R Workshop **Journal Article Critique Writing Assignment due today*
9 – Nov 9	In-person stats quiz.	Project Proposal Presentations (lightning talks 5 mins)
10 – Nov 16	R Workshop: Time Series Analysis **Problem Set 5 Introduced**	Work Period/Project Consultations **Seminar 4 Writing Assignment due today*
10 – Nov 23	R Workshop: PCA	**Seminar 5:** TBD *Optional Seminar 5 Writing Assignment due by Dec 10th.*
11 – Nov 30	Modelling Project Presentations (10 mins)	Modelling Project Presentations (10 mins)
12 – Dec 7	Murray Away, No Class	Murray Away, No Class

We will adhere to this schedule as much as possible. You will be informed of any necessary changes as we proceed through the course/semester.