GEOG 3902A/B – Selected Topics in Geography
Environmental Modelling

Course Outline: Section 001 Winter 2023

This course is taught in-person

1. Course Information

	Delivery Mode	Day/Time	Location
Lecture	In person	**Monday 2:30-4:30pm**	**UCC 63**
Lab	In person	**Wednesday 2:30-4:30pm**	**SSC 1059**

Classes Start	Spring Reading Week	Classes End	Study day	Exam Period
January 9	February 20-24	April 10	April 11-12	April 13-30

Course Instructor	Contact Information	Office Hours
Natasha MacBean	nmacbean@uwo.ca	MW 1:30-2:30pm

- Students will be able to drop into session on Mondays and Wednesdays from 1:30 to 2:30pm.
- Students will also be able to attend office hours via Zoom.

2. Calendar Description

This course introduces students to broad concepts of environmental modelling. We will learn about the main components of land surface/terrestrial ecosystem models and their role in climate change projections. These components include vegetation, carbon, hydrology and energy cycles, and how agriculture, land use change and land management impact ecosystem processes.

2 lecture and 2 lab hours, 0.5 course
Antirequisite(s): None
Prerequisite(s): At least 3rd year standing in a Geography & Environment, Biology, Environmental Science, or Earth Sciences program. Prerequisite checking is the student's responsibility

Senate Regulations state, "unless you have either the requisites for this course or written special permission from your Dean to enroll in it, you will be removed from this course and it will be deleted from your record. This decision may not be appealed. You will receive no adjustment to your fees in the event that you are dropped from a course for failing to have the necessary prerequisites."

3. Textbook

- PDFs of all readings will be posted in OWL.
- The following textbooks would be useful for extra reading for this course, but are not required. Copies will be available in during class and office hours.
    - Bonan, G. (2019) Climate Change and Terrestrial Ecosystem Modeling, 1st Edition, Cambridge University Press, UK.
    - Luo, Y. and Smith, B. (Eds.) (2022) Land Carbon Cycle Modeling: Matrix Approach, Data Assimilation, and Ecological Forecasting, 1st Edition, Taylor & Francis, USA.

4. Course Objectives and Format

Course Objectives

This course introduces students to environmental modelling from the perspective of terrestrial ecosystem models (TEMs). Students must have at least 3rd year standing in a Geography & Environment, Biology, Environmental Science, or Earth Sciences program. It is recommended that students have completed a course in physical geography, climate change, climatology, hydrology, biogeochemistry, biophysics, ecology, biogeography, or another related field.

TEMs – otherwise known as terrestrial biosphere models, land surface models, or dynamic vegetation models – typically form the land component of global scale earth system models (ESMs) that are used in Intergovernmental Panel on Climate Change (IPCC) climate change projections to model earth system responses to global environmental change. These models include short and long-term vegetation dynamics (phenology, species composition change), biogeochemical (carbon and nutrients), hydrology and energy cycles, as well as processes that impact ecosystems, such as disturbance, land use change and land management. We cover the foundations of these topics and learn how to encode the mathematical representation of these processes into computational models. The individual model components link together a wide variety of environmental modeling concepts and disciplines, including from the ecological, forest gap, carbon, vegetation demographic, catchment hydrology, and land use change modeling communities. Students therefore learn about a variety of different models used to study climate and environmental change impacts on the terrestrial biosphere at scales from ecosystems to the globe.

In lab exercises throughout the course, students will learn how knowledge of environmental, biogeochemical, and biophysical processes are translated into computational code used to run the models over long time periods and large spatial areas. Students will learn how to code a simple carbon cycle model, starting from the initial concept, through the equations, then the algorithm needed to implement the model, and finally writing the code (in Python). Students will then use this model to run experiments to understand how models work, and to learn how we use models to test scientific questions about ecosystem and environmental processes and their response to climate change. Some experience in computer programming would be helpful for the lab component of this course but is not necessary.

We will also learn about the history of TEM development (particularly within the context of climate change modeling), the challenges of developing models, the processes still missing in these models, and about quantifying and reducing model uncertainty via model-data integration. Students will also focus in depth on one specific component of environmental modelling that is pertinent to their interests, future research, and/or career goals via specific paper discussions and a final project.

This course should be useful for anyone interested in any aspect of how the terrestrial biosphere is responding to climate change and land use change/management. Understanding how TEMs work should equip students with the knowledge needed to better assess modelling studies that contribute to future climate change projections.

Course Format

Lecture (2 hours per week): Topics will be taught via lectures and paper discussions (typically 1 hour for lecture, and 1 hour for discussion of the readings for that week). Paper discussions will take place in In the final three weeks of the semester we will choose several papers related to environmental/land surface/terrestrial ecosystem modeling that are of interest to students' in the groups.

Labs (2 hours per week): Labs are designed to teach students the practicalities of building, running and using environmental models. The main part of the lab exercises will be focused on building, testing, and optimizing a simple carbon cycle model using computational programming code. Students will also be taught some foundational skills in Unix and Python programming in order to develop the scripts needed to build this model. Online modeling exercises will also be used. Students are not expected to have any prior programming skills or knowledge of high performance computing.

Attendance in class is not mandatory. Missed work should be completed within 1 week of the original deadline.

All course material will be posted to OWL: http://owl.uwo.ca. Any changes will be indicated on the OWL site and discussed with the class.

Google Chrome or Mozilla Firefox are the preferred browsers to optimally use OWL; update your browsers frequently. Students interested in evaluating their internet speed, please click here.

If students need assistance, they can seek support on the OWL Help page. Alternatively, they can contact the Western Technology Services Helpdesk. They can be contacted by phone at 519-661-3800 or ext. 83800.

5. Learning Outcomes

Course goals:

- Students will complete this course with a foundational knowledge of terrestrial environmental/ecosystem models, including how they are developed, and how they are used to make predictions about the response of the terrestrial biosphere to global climate and environmental change drivers. Students will be given a grounding in the basic principles of terrestrial ecosystem modeling from the overall concept to developing the equations, to writing the computational programming code needed to execute these models.

Learning outcomes:
Upon successful completion of this course, students should:

- Understand the basic components of terrestrial ecosystems and how these processes are encoded into computational environmental models: biogeochemical cycles, hydrology, energy budget, disturbances, dynamic vegetation, and anthropogenic land use and management.
- Have in-depth knowledge of one of these components depending on student's own interests and research (see Final Project).
- Know the steps needed for developing a simple environmental/ecosystem model, including: i) identifying the initial concept and purpose of the model; ii) understanding the mathematical equations; and iii) implementing these equations in scientific code that can be used to execute the model.
- Be able to use the model we have built together in class to understand how computational models of environmental and ecosystem processes operate, and how they can be used to make predictions, test scientific hypotheses and theories, and to ask new and exciting questions about the impact of climate and environmental change on terrestrial ecosystems.
- Be able to read and understand high impact scientific literature that tests hypotheses and describes predictions made with these models within the context of understanding the impact of global change drivers (e.g. climate change, CO2 emissions and land use change) on terrestrial ecosystems and the feedbacks to climate.
- Have a foundational understanding of what the IPCC is and the type of modeling used for IPCC climate change projections.
- Have a foundational level of knowledge about running computational models on high performance computing systems, including basic Unix commands and workflow, and introductory level Python programming knowledge.

6. Communication

☒ Students should check the OWL site every 24 – 48 hours

☒ A weekly update will be provided on the OWL announcements

☒ Students should email their instructor(s) and teaching assistant(s) using OWL "messages"

☒ For any other communication, the centrally administered **e-mail account** provided to students will be considered the individual's official university e-mail address. It is the responsibility of the account holder to ensure that e-mail received from the University at his/her official university address is attended to in a timely manner. You can read about the privacy and security of the UWO email accounts here.

☒ Emails will be monitored daily; students will receive a response in 24 – 48 hours

☒ This course will use Microsoft Teams for discussions

☒This course will use the OWL forum for discussions

Students should post all course-related content on the discussion forum so that everyone can access answers to questions

☒ The discussion forums will be monitored daily by instructors or teaching assistants

7. Course Content and Schedule

Week	Dates	Topic – Lecture	Topic – Lab	Readings
1	January 9-13	Introduction to the course	Intro to computational environmental modeling	CarbonBrief Explainer
2	January 16-20	History of land surface / ecosystem modeling	Online environmental modeling exercise	Prentice et al. (2015)
3	January 23-27	Energy balance modeling	Intro to Unix and Basic Python programming	Blyth et al. (2021)
4	Jan 30 – Feb 3	Hydrology Modeling	Intro to Lab exercises: Simple Carbon Cycle Model	Clark et al. (2015)
5	February 6-10	Carbon Cycle Modeling	Building a simple carbon cycle model	Rogers et al. (2017)
6	February 13-17	Vegetation Modeling	Model Evaluation	Fisher et al. (2018)
7	February 20-24	*Reading Week – No Class*		*N/A*
8	Feb 27 – Mar 3	Modeling agriculture and land management	Model Sensitivity Analysis	Pongratz et al. (2017)
9	March 6-10	Model evaluation and data assimilation	Data Assimilation exercise	MacBean et al. (2022)
10	March 13-17	IPCC and the Coupled Model Intercomparison Project (CMIP)	Carbon-climate modeling exercise	CarbonBrief Explainer
11	March 20-24	Specialist papers*	*Final Project*	TBD*
12	March 27-31	Specialist papers*	*Final Project*	TBD*
13	April 3 – 7	Specialist papers*	*Final Project*	TBD*

8. Evaluation

Course Assessment

Quizzes: There will be five open-book quizzes throughout the semester to test students' knowledge gained during the lectures and paper discussions on different parts of land surface and terrestrial ecosystem modeling. These quizzes will be on: 1) hydrology and energy balance modeling; 2) carbon and vegetation modeling; 3) modeling agriculture and land management; 4) model benchmarking and data assimilation; and 5) IPCC and climate modeling. Quizzes will taken on OWL. They will be timed (1 hr) and contain 20 questions each. Students will have two chances to complete the quiz and the highest grade will be taken.

Lab exercises: Six in-class exercises will be set for the main lab component part of the course. Two exercises will be comprehension questions using online modeling tools. Four lab exercises will be coding and comprehension exercises designed to teach students how to build, test, and optimize a simple carbon cycle model using computational programming code. The lab exercises will be assigned via OWL and the course GitHub page. Students will be using Python v3 and Jupyter Notebooks. Students will be introduced these programming tools prior to the start of these lab exercises. Students are expected to complete the assigned exercises and submit them by the deadline. Grades will be based on completing the assignments correctly. Answers to all lab exercises will be provided 1 week after the deadline.

Paper discussion: For each of the paper readings students are expected to submit one comment or question about the reading prior to the start of class each week. Questions will be given a mark of 1 for inadequate/unclear; 2 for adequate; or 3 for good/creative. A good or "creative" comment or question would push other participants in the discussion to think about the material further, or point out discrepancies or missing information from the readings. During the in-class group discussions on each paper, students are expected to share their questions or comments about the paper to contribute to the group discussion. Students will be taught methods of reading and discussing journal articles before reading the papers.

Final Project: Each student will complete a final class project. Students have two options:

1. Write a 3-5 page in-depth literature review on one part of the model (e.g., carbon cycle, or water cycle) and/or projections related to land surface/terrestrial ecosystem. Each student will be given a reading list relevant to their chosen topic, but they will be encouraged to seek out other journal articles to complement their knowledge. The grade will be based on the detail and quality of the literature review.
2. Perform a model-related computational analysis study using Python (e.g., model inter-comparison, evaluation of one component of a model against data, or develop a new model function for a specific process using data) and present the aims and results of their analysis in a 2-3 page summary of their project. Students will submit their code and the summary of project summary. The grade will be based on the quality of the analysis, code, and the summary description of their results.

Students can choose a topic of interest to them in consultation with the course instructor.

Potential class project topics:

- Modeling impacts of climate change at ecosystem to global scales
- Modeling impacts of rising CO_2 on plants/ecosystems

- Modeling impacts of drought on ecosystems
- Modeling impacts of changing water availability/streamflow
- Modeling disturbance (fires, insect outbreaks, etc)
- In depth study related to biogeochemical models: how to model carbon allocation, soil microbial processes, photosynthesis, phenology, nutrient limitations, etc.
- In depth study related to hydrology models: Snow modeling; spatial hydrology modeling, etc.
- Dynamic vegetation modeling (species competition etc)
- Model evaluation and inter-comparison studies (for a particular region or model output)

Grading

Below is the evaluation breakdown for the course. Any deviations will be communicated.

Assessment	Format	Weighting	Due Date (tentative)
Comprehension quizzes	5 per semester/via OWL	15%	Various – see OWL
Paper questions /discussion	12 per semester – due prior to class	15%	See Schedule
Lab exercises	6 per semester using Python in Jupyter Notebooks	35%	See Schedule
Final project	Literature review or model-related computational study	35%	1 week after final class

- Students are responsible for material covered in the lectures as well as the assigned chapters/sections in the text.
- Attendance is not mandatory but is strongly encouraged (particularly for the paper discussions during the 2nd hour of the lecture class). Both lectures and paper discussions will form the basis of the comprehension quizzes.
- Software needed for the lab exercises will be installed in the computer lab in Social Sciences Center. Students are responsible for installing relevant software on their own computers if they want to work on the lab exercises outside the SSC computer lab (advice will be given from the course instructor.
- Students must attend the lab classes if they require assistance with lab exercises.
- All assignments are due at 11:55 pm EST unless otherwise specified
- Written assignments will be submitted to Turnitin (statement in policies below)
- Students will have unlimited submissions to Turnitin
- Rubrics will be used to evaluate assessments and will be posted with the instructions on OWL.
- After an assessment is returned, students should wait 24 hours to digest feedback before contacting their evaluator; to ensure a timely response, reach out within 7 days

Click here for a detailed and comprehensive set of policies and regulations concerning examinations and grading. The table below outlines the University-wide grade descriptors.

A+	90-100	One could scarcely expect better from a student at this level
A	80-89	Superior work which is clearly above average
B	70-79	Good work, meeting all requirements, and eminently satisfactory
C	60-69	Competent work, meeting requirements
D	50-59	Fair work, minimally acceptable
F	below 50	Fail

Information about late or missed evaluations:

- Late assessments without illness self-reports (or another university recognised absence) will be subject to a late penalty 25%/day
- Late assessments with illness self-reports (or with a reported university recognised absence) should be submitted within 1 week of submission of the last illness self-report
- An assessment cannot be submitted after it has been returned to the class; an alternate assessment will be assigned.
- A make-up test will be offered on the following dates:

Grades will not be adjusted on the basis of need. It is important to monitor your performance in the course. Remember: *You* are responsible for your grades in this course.

9. Accommodation Policies

Students with disabilities work with Accessible Education (formerly SSD) which provides recommendations for accommodation based on medical documentation or psychological and cognitive testing. The accommodation policy can be found here: Academic Accommodation for Students with Disabilities.

Academic Consideration for Student Absence

Students will have up to two (2) opportunities during the regular academic year to use an on-line portal to self-report an absence during the term, provided the following conditions are met: the absence is no more than 48 hours in duration, and the assessment for which consideration is being sought is worth 30% or less of the student's final grade. Students are expected to contact their instructors within 24 hours of the end of the period of the self-reported absence, unless noted on the syllabus. Students are not able to use the self-reporting option in the following circumstances:

- for exams scheduled by the Office of the Registrar (e.g., December and April exams)
- absence of a duration greater than 48 hours,
- assessments worth more than 30% of the student's final grade,
- if a student has already used the self-reporting portal twice during the academic year

If the conditions for a Self-Reported Absence are *not* met, students will need to provide a Student Medical Certificate if the absence is medical, or provide appropriate documentation if there are compassionate grounds for the absence in question. Students are encouraged to contact their Faculty academic counselling office to obtain more information about the relevant documentation.

Students should also note that individual instructors are not permitted to receive documentation directly from a student, whether in support of an application for consideration on medical grounds, or for other reasons. **All documentation required for absences that are not covered by the Self-Reported Absence Policy must be submitted to the Academic Counselling office of a student's Home Faculty.**

For Western University policy on Consideration for Student Absence, see

Policy on Academic Consideration for Student Absences - Undergraduate Students in First Entry Programs

and for the Student Medical Certificate (SMC), see:

http://www.uwo.ca/univsec/pdf/academic_policies/appeals/medicalform.pdf.

Religious Accommodation

Students should consult the University's list of recognized religious holidays, and should give reasonable notice in writing, prior to the holiday, to the Instructor and an Academic Counsellor if their course requirements will be affected by a religious observance. Additional information is given in the Western Multicultural Calendar.

10. Make-up Examinations

Makeups will be granted with approved documentation only. All documentation for missed exams must be provided to the Academic Counselling Office within 48 hours of the scheduled exam, otherwise the instructor will assign a grade of zero.

The format and content of make-ups may differ substantially from the scheduled test or examination.

11. Use of Electronic Devices

No electronic devices will be allowed during tests and examinations.