ABE6649C- Advanced Biological Systems Modeling

Sections BSMG (24367), REC (2480) and ABMO (2481)

Spring Semester 2026

Spring 2026: 3 credits

Lectures: Monday and Friday 8:30-9:20 and Wed 3-6 pm
Venue: Rogers Hall - In person in Room 282 required for students registered for on campus sections, with Online/CANVAS/Zoom required for students registered for remote (hybrid) class sections.

Instructors:

Dr. Rafael Muñoz-Carpena, Distinguished Professor
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Dr. Henry Medeiros, Associate Professor
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Dr. Greg Kiker, Professor and Chair
Dept. of Agricultural and Biological Engineering, Rogers Hall, Room 120a
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Pre-requisites: This course requires ABE 5643C as a prerequisite or by approval from the instructors.

General Description and Objectives: This course serves as an advanced graduate class for continued modeling of biological processes and systems. It is the second and required course of the Biological Modeling Certificate offered by ABE (http://www.abe.ufl.edu/academics/graduate/certificate-biological-systems-modeling.shtml).

The course extends and deepens the curriculum of ABE5643C in that it covers more advanced modeling topics such as: (1) hands-on experience and confidence in formulating, solving (analytically and numerically with R, Python and other programming languages), (2) interpreting the output of dynamic biological ODEs; (3) object-oriented design and programming and agent-based model development, (4) High Performance Computing (HPC), (5) HPC and Global Sensitivity and Uncertainty Analysis towards subjects of specific interest, (6) Inverse Modeling, (7) Graphics Processing Unit (GPU) computing on HPC systems.

It is expected that students will have access to their own computer for this course, and the ABE department also offers the computer lab for class work and off class hours for

assignments. Additionally, access to the UF HyperGator Facility will be provided through this class.

Several different computer programming languages will be used in this course. Freeware compilers and platforms will be used to compile and execute these languages in class and on students' own computers. While some class time will be devoted to programming design, syntax and debugging, it is expected that the student will spend additional time outside of class to deepen knowledge on these languages started in the previous course ABE5463C

Class Objectives/Outcomes: At the close of this course, the student will be able to:

3 Conceptualize, design and implement a variety of intermediate and advanced biological system models
   - Translate biological concepts into Python, R code and Unified Modeling Language
   - Translate object and algorithm designs into equations and computer code

4 Obtain working knowledge of unix command line processing and scripting, and HPC job processing fundamentals.

5 Utilize advanced model analysis software and tools to objectively test and parameterize models against measured data using unix-based HPC systems.

6 Assess model performance under uncertain input conditions to analyze models of varying complexity for performance and stability of solutions

7 Explore and code in newer modeling styles (agent-based) as well as develop and execute code on novel computing platforms (HPC-based and GPU-based)

8 Implement and evaluate stochastic modeling and estimation methods using advanced GPU computing techniques.

Course Format: All topics are delivered through the CANVAS software and will be introduced in the class. The class is team-taught among Profs. Kiker, Muñoz-Carpena and Medeiros. Attendance to all class lectures and laboratories is required. Students registered for on campus sections of this course are required to attend in person. Students registered for online (remote) class sections are required to attend on ZOOM. Students in class sections must obtain instructor approval to attend on ZOOM rarely and under special circumstances.

Course Outline and Schedule (subject to changes/alterations):

Weeks 1-3: Advanced Modeling Concepts (Kiker Section): Jan 12 - Jan 30

1. **Review of Advanced Biological Modeling Concepts:** This section reviews coding skills from ABE5643C and introduces Probabilistic Models through Monte-Carlo Modeling, Modeling of Sampling Processes, Random Walk/Related Stochastic Processes, Markov Chain Simulation.

2. **Agent-Based Modeling and Object-Oriented Design:** This section covers an introduction to Object-Oriented Design (OOD) and elementary OO programming

concepts. A simple java-based, object-oriented, agent-based model (Muttons & Gluttons) will be used to explore predator/prey relations along with NetLogo-based examples. Students will simulate simple biological systems in Monte-Carlo fashion and summarize results. A Java-Archive (JAR) executable file will be created by the students for further simulation on the UF HiPer Gator (Unix) system along with Global Sensitivity Analysis and Monte-Carlo Filtering.

Weeks 4-10: High Performance Computing and applications (Muñoz-Carpena Section): February 2-March 20:
This section covers most of the remaining portion of the class and covers:

1. **Large-scale, unix-based simulation and uncertainty analysis using the HiPer Gator platform** (https://www.rc.ufl.edu/services/hipergator/_). This section begins with a a crash course in using the Unix operating system along with executable scripts and rudiments of HPC job management (SLURM)
2. Review of Global Sensitivity and Uncertainty Analysis (GSUA) concepts covered in ABE5643C and application to large problems in the HPC. The primary objective is to conduct large-scale, Global Sensitivity and Uncertainty Analysis along with Monte-Carlo Filtering to highlight potential system features and controls.
3. Advanced GSUA applications: a) Sobol-based inverse model calibration with Global search and local refinement, b GSUA of stochastic models.

Weeks 11-15: Sequential Monte Carlo Estimation using GPU computing (Medeiros Section): (March 23- April 22)
This section introduces techniques and tools for multidimensional state estimation using Sequential Monte Carlo methods. It focuses on the challenges of estimating high-dimensional state vectors that exhibit dynamic spatio-temporal behaviors. Topics covered in this section will be implemented using cutting-edge GPU computing tools for probabilistic programming. Specifically, this section covers:

1. Multidimensional State Estimation using Sequential Monte Carlo Methods: Introduction to multidimensional dynamic system modeling and state prediction, likelihood functions and state updates, as well as the curse of dimensionality and strategies to address sampling challenges, such as resampling techniques.
2. System Models: Dynamic system modeling techniques, including traditional linear and non-linear models, as well as recent approaches based on artificial intelligence methods.
3. Likelihood Models: Traditional likelihood modeling techniques for multi-dimensional state estimation problems and examples of state-of-the-art AI-based methods.
4. Spatio-temporal State Estimation using Particle Filters: Techniques to simultaneously estimate multiple dynamic state vectors. A case study on plant tracking using robotic platforms will be used to introduce cutting-edge likelihood and dynamic models.

Course Texts (accessed through Course Management System or UF Libraries):

- Keen, R.E. and Spain, J.D. 1992. Computer Simulation in Biology: a BASIC introduction. Wiley-Liss. ISBN: 0-471-50971-X. (accessed via CANVAS)

- Selected journal articles and web links are provided in CANVAS within the teaching modules, along with software and articles via Prof Muñoz-Carpena's website (https://abe.ufl.edu/faculty/carpena/software/index.shtml)

Recommended software (all open-source and freely available):

As models are developed in a variety of platforms and styles, this course will expose students to some of the major groups of languages. The following list covers some of the potential tools covered in this class.

- Procedural languages (Open Source)
  - Python – http://www.python.org
  - Anaconda Open Source Development Tools for Python: https://www.anaconda.com/download
- Object-oriented design and programming (Open Source)
  - Unified Modeling Language (UML) Design: Star UML (https://staruml.io/)
  - IntelliJ IDEA: Integrated Development Environment (https://www.jetbrains.com/community/education/#students) with Java (www.java.com)
  - Eclipse Integrated Development Environment (www.eclipse.org) with Java (www.java.com)
- Free form environmental models (using Object-oriented implementation) (Open Source)
  - NetLogo – Agent-Based Modeling (http://ccl.northwestern.edu/netlogo/)
- Statistical languages (Open Source)
  - R - http://www.r-project.org/
  - R Studio - https://posit.co/download/rstudio-desktop/
- Model analysis software
  - SIMLAB (https://ec.europa.eu/jrc/en/samo/simlab)
  - Sensitivity packages in R and Python.

Assignments: As with its prerequisite course (ABE5643C), this course is primarily graded on a series of assignments (approximately 6 to 9) to create an overall term project/portfolio. Each student will submit individual written reports, designs and/or presentations that will be graded by the instructor. *In some cases, short quizzes (Pass/Fail/Retry) may also be included as part of individual homework grades. These CANVAS-based quizzes are used to ensure that students are reading and understanding lecture/preparatory materials prior to homework assignments.* ***NOTE: Students must turn in all class assignments. ALL class assignments must be submitted before the last day of class.***

- HW1-2 Review of Biological Modeling Concepts and Probabilistic Modeling (Prof. Kiker)
  - HW 1: Assigned Lab Period Week 1 – Due Lab Period Week 2
  - HW 2: Assigned Lab Period Week 2 – Due Lab Period Week 3

- HW 3-4: Object-Oriented Design, Programming and Modeling. Agent-Based Modeling for Biological Systems; Monte-Carlo Style Simulation (Prof. Kiker)
    - HW 3: Assigned Lab Period Week 3 – Due Lab Period Week 4
    - HW 4: Assigned Lab Period Week 3 – Due Lab Period Week 5
- HW 5-7: High Performance Computing (HPC), Global Sensitivity and Uncertainty Analysis and Monte Carlo Filtering, Inverse Modeling and GSA of Stochastic Models (Prof. Carpena)
    - HW 5: Assigned Lab Period Week 4 – Due Lab Period Week 6
    - HW 6: Assigned Lab Period Week 6– Due Lab Period Week 8
    - HW 7: Assigned Lab Period Week 8 – Due Lab Period Week 11
- HW 8-10: Sequential Monte Carlo and GPU Computing
    - HW 8: Assigned Lab Period Week 11 – Due Lab Period Week 13
    - HW 9: Assigned Lab Period Week 13 – Due Lab Period Week 14
    - HW 10: Assigned Lab Period Week 14 – Due Lab Period Week 15

Assignments: This course will utilize the E-Learning (CANVAS) system for the submission of all homework assignments. No assignment will be accepted by email or other means.

GRADING:
Class Assignments: 100%

- Homework will be assigned and will be due up to 7 - 14 days later.
- Late homework will be accepted at a cost of 10% per day late (Up to a maximum of 50%).
- 100% submission policy: All class assignments must be submitted before the end of the course to obtain credit. Missing any assignment will result in an I (incomplete) grade.

GRADING SCALE;

A: 93 ≤ Average ≤ 100; A-: 90 ≤ Average < 93
B+: 87≤ Average < 90; B : 83≤ Average < 87; B- : 80≤ Average < 83;
C+: 77≤ Average < 80; C : 73≤ Average < 76; C- : 70≤ Average < 73;
D+: 67≤ Average < 69; D : 63≤ Average < 67; D- : 60≤ Average < 63;
E : ≤ Average =< 60

More information on UF grading policy may be found at:
UF Graduate Catalog
Grades and Grading Policies

Students Requiring Accommodations
Students with disabilities who experience learning barriers and would like to request academic accommodations should connect with the Disability Resource Center. It is important for students to share their accommodation letter with their instructor and discuss their access needs, as early as possible in the semester.

Course Evaluation
Students are expected to provide professional and respectful feedback on the quality of instruction in this course by completing course evaluations online via GatorEvals. Students will be notified when the evaluation period opens, and can complete evaluations through the email they receive from GatorEvals, in their Canvas course menu under GatorEvals, or via ufl.bluera.com/ufl/. Summaries of course evaluation results are available to students here.

University Honesty Policy
UF students are bound by The Honor Pledge which states, "We, the members of the University of Florida community, pledge to hold ourselves and our peers to the highest standards of honor and integrity by abiding by the Honor Code. On all work submitted for credit by students at the University of Florida, the following pledge is either required or implied: "On my honor, I have neither given nor received unauthorized aid in doing this assignment." The Honor Code specifies a number of behaviors that are in violation of this code and the possible sanctions. Furthermore, you are obligated to report any condition that facilitates academic misconduct to appropriate personnel. If you have any questions or concerns, please consult with the instructor or TAs in this class.

Software Use
All faculty, staff, and students of the University are required and expected to obey the laws and legal agreements governing software use. Failure to do so can lead to monetary damages and/or criminal penalties for the individual violator. Because such violations are also against University policies and rules, disciplinary action will be taken as appropriate. We, the members of the University of Florida community, pledge to uphold ourselves and our peers to the highest standards of honesty and integrity.

Student Privacy
There are federal laws protecting your privacy with regards to grades earned in courses and on individual assignments. For more information, please see the Notification to Students of FERPA Rights.

Campus Resources:

Health and Wellness

U Matter, We Care:
If you or a friend is in distress, please contact umatter@ufl.edu or 352 392-1575 so that a team member can reach out to the student.

Counseling and Wellness Center: counseling.ufl.edu/cwc, and 392-1575; and the University Police Department: 392-1111 or 9-1-1 for emergencies.

Sexual Assault Recovery Services (SARS)
Student Health Care Center, 392-1161.

University Police Department at 392-1111 (or 9-1-1 for emergencies), or police.ufl.edu.

Academic Resources

E-learning technical support, 352-392-4357 (select option 2) or e-mail to Learning-support@ufl.edu.

Career Resource Center, Reitz Union, 392-1601. Career assistance and counseling.

Library Support, Various ways to receive assistance with respect to using the libraries or finding resources.

Teaching Center, Broward Hall, 392-2010 or 392-6420. General study skills and tutoring.

Writing Studio, 302 Tigert Hall, 846-1138. Help brainstorming, formatting, and writing papers.

Student Complaints Campus

On-Line Students Complaints