EE 585 - Ecological Forecasting and Informatics
Spring 2021

Time: MWF 10:10-11:00
Location: PRB 148

Professor: Michael Dietze
STO 457A
dietze@bu.edu

Office Hours: Mon 12-1PM
Fri 2-3PM
or by appointment

Course Web Page: **https://ecoforecast.org/ee-585-2021/**

Course Description:

Ecological forecasting is the process of predicting the state of ecosystems, ecosystem services, and natural capital, with fully specified uncertainties, and contingent on explicit scenarios for climate, land use, human population, technologies, and economic activity. The backbone of this course covers topics related to the statistics and informatics of model-data fusion and forecasting: data management, workflows, Bayesian statistics, uncertainty partitioning, propagation, and analysis, fusing multiple data sources, assessing model performance, scenario development, decision support, and a suite of data assimilation techniques. Interspersed among these technical sections are case studies on specific ecological subdisciplines that aim to highlight the successes and failures of ecological forecasting in each: natural resources; endangered species; invasive species; epidemiology; and the carbon cycle.

Prerequisite:

- BI 303 or BI 306
  A basic knowledge of ecological models as one would get from a general ecology class (e.g. logistic growth).
- MA 121 or MA 123
  Previous exposure to college-level math (need not be recent, but you should understand the ideas behind logarithms, sums, integrals, etc. if not their details)
- EE 375, EE 509, or EE 516 or consent of instructor
  A statistics or modeling course that provided some exposure to basic probability concepts and distributions and experience with the R script language.

Course Objectives:

After taking this course, you should be able to generate an operational forecast from a simple model that makes use of more than one data stream. You should be able to categorize and estimate the uncertainties in the model, propagate this uncertainty into the forecast, and assess the performance of the model. You should be able to explain the following: the model, the data, the forecast, and the best practices employed for managing all three. You should be able to assess and critique forecast data products and scientific publications about ecological forecasts.

HUB Requirements

Teamwork/Collaboration

1. *As a result of explicit training in teamwork and sustained experiences of collaborating with others, students will be able to identify the characteristics of a well-functioning team.*
   EE585 provides explicit teamwork training through readings about team science, group discussions, and a hands-on training activity on collaborative code development using Github. Students gain sustained experience in applying these interpersonal, organizational, and technical skills through the numerous milestones of a semester-long group project.
2. *Students will demonstrate an ability to use the tools and strategies of working successfully with a diverse group, such as assigning roles and responsibilities, giving and receiving feedback, and engaging in meaningful group reflection that inspires collective ownership of results.*
   Students will demonstrate the use of collaborative tools and strategies through a semester-long group project. One course discussion period is explicitly set aside for group reflection, which occurs not at the end of the project, but going into the final month (i.e. crunch time), providing an opportunity for course corrections in the team's dynamics. Student will report these reflections to the class orally.

Oral/Signed Communication

1. *Students will be able to craft and deliver responsible, considered and well-structured oral and/or signed arguments using media and modes of expression appropriate to the situation.*
   EE585 involves a semester-long group project focused on the development of a simple ecological forecast. Students will present the results of this project in a formal oral presentation, open both to the class and the wider department, in the style of a scientific conference talk (15 min talk, 10 min Q&A). Students will use media appropriate to such a talk, such as PowerPoints that include text, images, charts, tables, and animations. While a group project, students are expected to spend equal time presenting and responding to questions.
2. *Students will demonstrate an understanding that oral/signed communication is generally interactive, and they should be able to attend and respond thoughtfully to others.*
   In addition to the Q&A portion of the formal group project presentation, almost 1/3 of the course is set aside for group discussions, where students are expected to interact closely with their peers and the instructor and respond thoughtfully to the discussion. All students rotate at least once through the responsibility of being the moderator for that week's discussion, which requires them to send potential group discussion questions/prompts

to the instructor ahead of time to ensure they are prepared to keep the discussion rolling and on target. Each student will also rotate at least once through the role of rapporteur, where they summarize the discussion from their group for the whole class.

3. *Students will be able to speak/sign effectively in situations ranging from the formal to the extemporaneous and interact comfortably with diverse audiences.* Students will speak in a range of settings, spanning from the formal course presentation, to leading a group discussion, to acting as the rapporteur who extemporaneous reports group discussions back to the whole class, to routinely participating in the informal group discussions.

Ethical Reasoning:

1. *Students will be able to identify, grapple with, and make a judgment about the ethical questions at stake in at least one major contemporary public debate, and engage in a civil discussion about it with those who hold views different from their own.*
   Environmental change writ large (climate change, biodiversity loss, land use and disturbance/wildfire, invasive species, etc.) remains a major area of contemporary public debate and is a central focus of EE585. In addition to these broader debates, students will also grapple with important considerations in scientific ethics, such as the ethics of forecasting, open science (e.g. forecasting requires low-latency data but individuals need to a first shot at analyzing their own data; research needs to be reproducible but some data can't be shared [e.g. medical records, endangered species]), communicating uncertainties, and where do we draw the line between forecasts that should be public goods (e.g. emergency alerts) versus private sector innovation. Students will engage with these questions through a combination of civil small-group discussions and a written assignment.
2. *Students will demonstrate the skills and vocabulary needed to reflect on the ethical responsibilities that face individuals (or organizations, or societies or governments) as they grapple with issues affecting both the communities to which they belong and those identified as "other." They should consider their responsibilities to future generations of humankind, and to stewardship of the Earth.*
   Through assigned readings, lectures, and in-class discussions EE585 will provide students with the skills and vocabulary needed to reflect on, and grapple with, the scientific and societal ethical issues around ecological forecasting and its role in the stewardship of the earth. Students will explicitly demonstrate these skills and vocabulary through both formative (in class discussion) and summative assessment (written assignment on forecasting as a public good versus private sector innovation).

Technology:

Slack:

Students are encouraged to use Slack as part of the course, such as to ask question, discuss hands-on activities, and coordinate the semester project. The primary course slack will be the #ee585_2021 channel within the "Quantitative Environmental Education" Slack that Prof Dietze uses for all of his courses: qeegroup.slack.com
Invite link: https://join.slack.com/t/qeegroup/shared_invite/zt-kzelwij9-6igDAanIqjPlt~rhD3ffRg

In addition to the course-specific Slack, you are strongly encouraged to join the Ecological Forecasting Initiative's Slack, ecoforecast.slack.org , as part of the semester project. In particular the #neon4cast_courses channel is a shared space for students participating in the forecasting challenge (across universities) and there are individual #neon4cast channels for each specific challenge. If your interest in forecasting grows you might also check out some of the working group channels or the EFI student association #students.
Invite link: https://join.slack.com/t/ecoforecast/shared_invite/zt-l5od1yk1-Ulc777kMCWT0H~YClpt4Jg

Phones:
The use of phones in class is prohibited. This includes texting, email, and all other smartphone apps.

Laptops/tablets:
Students are encouraged to bring laptops and/or tablets for the purpose of taking notes, bringing papers for discussions, etc. **Laptops are required from most hands-on activities**.

R:
Most hands-on activities and final projects will employ R for data management, analysis, and modeling. R instructions will be given assuming the user is running the RStudio editor. Therefore **it would also be good to install R** http://www.r-project.org **and RStudio** http://www.rstudio.com. A few other pieces of software will be used for individual in-class activities and introduced on a case-by-case basis.

The first hands-on activity for the class is a R tutorial, which includes references to other R resources

If you want to avoid running computationally-intensive analyses on your personal computer / laptop, you may want to try running RStudio Server through the SCC OnDemand web interface, which will allow you to run jobs on BU SCC cluster (BU only). You should have received an email from BU IS&T letting you know that your account on the BU cluster has been set up.

Git/Github:
Similarly, most hands-on activities and final projects will make extensive use of Git (for version control) and Github (https://github.com) (for project management), which not coincidentally is also integrated with RStudio. **You will want to sign-up for an account**

on Github and then send me your username so I can add you to the class/book repository, https://github.com/EcoForecast

If you are unfamiliar with Git and Github good place to start is the GitHub 5 minute illustrated tutorial. In addition, there are three fun tutorials for learning git:

- Learn Git is a great web-based interactive tutorial.
- LearnGitBranching
- TryGit.

Also note that Hands-on Activity 4 will focus on learning how to use Git collaboratively

Course Format & Outline:

In this course we will approach most topics from three perspectives, each occupying one course day. The first is a lecture providing a background and foundation on each topic. The second is an in-class activity aimed at gaining practical hands-on experience with the relevant tools and techniques. The third is a group discussion of the latest literature on the topic.

Topics and readings are subject to change. Changes will be announced in class and posted on the course website.

Day	Topic	Activity	Reading (O = optional)
1/25	Intro/Syllabus	Lecture	Preface
1/27	Overview	Lecture	Chapter 1
1/29	The command prompt is my friend	Hands-on	1. R primer O: Google R tutorials O: Git/Github tutorials
2/1	From models to forecasts	Lecture	Chapter 2 (Currie 2019)
2/3	Logistic Growth	Hands-on	2. From Models to Forecasts
2/5	Dynamic Models	Lecture	TBA
2/8	Data, large and small	Lecture	Chapter 3 O: Data One Best Practices
2/10	Open Science	Discussion	(Powers and Hampton 2019)
2/12	Tools for big data	Hands-on	3. Big Data
2/16 Tues	Informatics of Model-Data Fusion	Lecture	Chapter 4 Team Science: (Read et al. 2016)
2/17	Workflows	Hands-on	Pair Coding
2/19	Forecast Ethics	Discussion	(Hobday et al. 2019)
2/22	Intro to Bayes	Lecture	Chapter 5 O: (Ellison 2004) O: Bayesian Regression
2/24	BUGS/JAGS	Hands-on	JAGS Primer
2/26	Expert Elicitation	Discussion	(Morgan 2014)
3/1	Characterizing Uncertainty	Lecture	Chapter 6 O: Fitting Uncertainties O: Hierarchical Bayes

3/3	State-space models	Lecture	Chapter 6
3/5	State-space models	Hands-on	Chapter 8 6. State Space
3/8	Invasive species	Discussion	(Ibanez et al. 2014)
3/10	Fusing data sources	Lecture	Chapter 9
3/12	Data-Fusion	Hands-on	8. Tree Rings O: (Clark et al. 2007)
3/15	Biodiversity	Discussion	Chapter 7
3/17	Propagating Uncertainty	Lecture	Chapter 11
3/19	Uncertainty Partitioning	Hands-On	Uncertainty Partitioning O: (Dietze 2017)
3/22	Carbon	Discussion	Chapter 12
3/24	Data Assimilation: Analytical	Lecture	Chapter 13 O: (Wikle and Berliner 2007)
3/26	Kalman Filter	Hands-on	9. Kalman Filter
3/29	Data Assimilation: Monte Carlo	Lecture	Chapter 14 O: (Evensen 2009)
3/31	BU Wellness Day	<no class>	<no class>
4/2	Ensemble KF	Hands-on	10. Particle Filter
4/5	Infectious disease	Discussion	Chapter 15
4/7	Assessing Model Performance	Lecture	Chapter 16
4/9	Model Assessment	Hands-on	11. Model Assessment
4/12	Teamwork SWOT	Discussion	No reading
4/14	Scenarios & Decision Support	Lecture	Chapter 17
4/16	Stakeholder exercise	Hands-on	Activity
4/19	NO CLASS		Patriot's Day
4/21	Decision Support	Discussion	(Memarzadeh and Boettiger 2019, Miller et al. 2019)
4/23	Final projects	Hands-on	
4/26	Final projects	Hands-on	
4/28	Final Thoughts	Lecture	Chapter 18 (Dietze et al. 2018)
5/4 9-11	FINAL	Presentation	

University Policy on Religious Observance
http://www.bu.edu/chapel/religion/

Multifaith Calendar
http://www.interfaithcalendar.org/

Grading:

Hands-on activities	4 points each	48
Discussions	2.5 points each	20

Essay	6 points	06
Final Project	24 points	24
		100

It is the student's responsibility to know and understand the provisions of the Academic Conduct Code. Cases of suspected academic misconduct will be referred to the Dean's Office.

Discussions **Approx. weekly**

For the discussions we will break into small groups and students will rotate through the role of moderator on a week-by-week basis. In addition to the paper suggested by the instructor, **the moderator is expected to find and share one additional journal article on that week's topic to be read by the group**, which should be distributed no later than 5 days before the discussion. Examples of relevant papers can be found in EFI Zotero group, the Oxford Bibliography on Ecological Forecasting or by searching Google Scholar / Web of Science.

Moderators are expected to keep the discussion on topic and moving forward, and to prepare questions to promote discussion. These **questions should be emailed to the instructor no later than midnight the evening before** the discussion.

To ensure effective group discussions, the class will split into 2-3 subgroups for the discussion periods. At the end of each class the group note-taker/rapporteur will briefly summarize the key points of their group's discussion for the rest of the class.

Hands-on Activities **Weekly**

The requirements for the hand-on activities will vary from week-to-week but generally involve the exploration and application of a new tool or technique. These assignments need to be **submitted on BLACKBOARD by the start of class the following week**.

Research Project **Numerous milestones**

The goal of the final research product is to generate an automated forecast for a specified ecosystem state. This year projects will be selected from among the forecast areas of the Ecological Forecasting Initiative's NEON Forecasting Challenge. At the start of the project you will begin by developing an uncalibrated process model that could be informed by one or more publicly available data streams. You will calibrate and validate the model against training data, assess and quantify the sources of uncertainty that contribute to the forecast, and then produce an initial forecast. After this you will generate of updates to your forecast given new data and assess the skill of your previous forecasts against this new data. Forecasts will be embedded in a workflow and the instructor must be able to further update the forecast using this workflow (i.e. the analysis needs to be transparent and repeatable). The 'final' for the course will be a brief presentation (10 min) and oral defense (10 min) of the analysis.

Students will work in small groups for the final project and students are strongly encouraged to work on the project throughout the semester as they are introduced to each topic. The overall project is broken up into a series of smaller milestones and due dates throughout the semester, as detailed in the course project document.

Forecast Ethics Essay 2/28/2021

Write a 3-5 page essay exploring the issue of how and where we ethically draw the line between ecological forecasts that should be considered "public goods" versus those that might operate as "private goods." To make an analogy to weather forecasting, numerical weather forecasts are currently provided freely by the government (NOAA) as a public good, but there are many private companies innovating in this area and providing specialized services for a fee. At one end of the spectrum of services are emergency alerts (e.g. tornadoes, hurricanes, floods, etc.) -- most people feel it would be unethical to exclude individuals from receiving an alert about a potentially life-threatening situation. But what if a private company develops an alert that is faster than the governments? Are they required to provide it to the public for free? And how do factors such as the background rate of the risk, the rate of false positives, and the stage of forecast development and validation (e.g. NASA/NOAA Technological Readiness Level) affect this decision. Where are the analogous ethical boundaries in ecological forecasting? How do we navigate them in a way that balances both short-term and long-term needs (e.g. it may be easy in the short-term to say all forecasts should be public goods, but would that results in less investment in forecast development, technology, and innovation?). Are there ecological forecasts that categorically should not be public goods? What are the ways we as a young discipline might advocate for and enforce ethical norms in ecological forecasting?

Attendance, make-ups, and late work:

As per university policy, students are expected to attend class:
http://www.bu.edu/academics/resources/university-policies/attendance/
Students who expect to be absent from class for more than five days should notify their dean promptly. Dr. Dietze will negotiate make up activities and extensions only if the dean excuses the absence.

For the hands-on activities and final project, **points will be deducted at 10% per day for any unexcused late work**.

Academic Conduct Code
http://www.bu.edu/cas/students/graduate/grs-forms-policies-procedures/academic-discipline-procedures/

Textbook:

The textbook for the class should be available from the campus bookstore or online (Amazon, Princeton University Press, etc)

Dietze MC. *Ecological Forecasting*. Princeton, NJ: Princeton University Press; 2017.

Readings:

All readings will be made available on the course webpage:

Clark, J. S., S. R. Carpenter, M. Barber, S. Collins, A. Dobson, J. A. Foley, D. M. Lodge, M. Pascual, R. Pielke Jr, W. Pizer, C. Pringle, and W. V Reid. 2001. Ecological forecasts: an emerging imperative. Science 293:657–60.

Clark, J. S., M. S. Wolosin, M. C. Dietze, I. Ibáñez, S. LaDeau, M. Welsh, and B. Kloeppel. 2007. Tree growth inference and prediction from diameter censuses and ring widths. Ecological Applications 17:1942–53.

Currie, D. J. 2019. Where Newton might have taken ecology. Global Ecology and Biogeography 28:18–27.

Dietze, M. C. 2017. Prediction in ecology: a first-principles framework. Ecological Applications 27:2048–2060.

Dietze, M. C., A. Fox, L. M. Beck-Johnson, J. L. Betancourt, M. B. Hooten, C. S. Jarnevich, T. H. Keitt, M. A. Kenney, C. M. Laney, L. G. Larsen, H. W. Loescher, C. K. Lunch, B. C. Pijanowski, J. T. Randerson, E. K. Read, A. T. Tredennick, R. Vargas, K. C. Weathers, and E. P. White. 2018. Iterative near-term ecological forecasting: Needs, opportunities, and challenges. Proceedings of the National Academy of Sciences 115:1424–1432.

Ellison, A. M. 2004. Bayesian inference in ecology. Ecology Letters 7:509–520.

Evensen, G. 2009. The Ensemble Kalman Filter for Combined State and Parameter Estimation. IEEE Control Systems Magazine:83–104.

Hobday, A. J., J. R. Hartog, J. P. Manderson, K. E. Mills, M. J. Oliver, A. J. Pershing, and S. Siedlecki. 2019. Food for Thought Ethical considerations and unanticipated consequences associated with ecological forecasting for marine resources.

Ibanez, I., J. M. Diez, L. P. Miller, J. D. Olden, C. J. B. Sorte, D. M. Blumenthal, B. A. Bradley, C. M. D'Antonio, J. S. Dukes, R. I. Early, E. D. Grosholz, and J. J. Lawler. 2014. Integrated assessment of biological invasions. Ecological Applications 24:25–37.

Luo, Y., J. T. Randerson, G. Abramowitz, C. Bacour, E. Blyth, N. Carvalhais, P. Ciais, D. Dalmonech, J. B. Fisher, R. Fisher, P. Friedlingstein, K. Hibbard, F. Hoffman, D. Huntzinger, C. D. Jones, C. Koven, D. Lawrence, D. J. Li, M. Mahecha, S. L. Niu, R. Norby, S. L. Piao, X. Qi, P. Peylin, I. C. Prentice, W. Riley, M. Reichstein, C. Schwalm, Y. P. Wang, J. Y. Xia, S. Zaehle, and X. H. Zhou. 2012. A framework for benchmarking land models. Biogeosciences

9:3857–3874.

Memarzadeh, M., and C. Boettiger. 2019. Resolving the measurement uncertainty paradox in ecological management. Arxiv preprint.

Miller, S., A. Rassweiler, L. Dee, K. M. Kleisner, T. Mangin, R. Oliveros-ramos, J. Tam, F. P. Chavez, M. Ñiquen, S. E. Lester, M. Burden, S. Gaines, and C. Costello. 2019. Optimal harvest responses to environmental forecasts depend on resource knowledge and how it can be used. Canadian Journal of Fisheries and Aquatic Sciences.

Morgan, M. G. 2014. Use (and abuse) of expert elicitation in support of decision making for public policy. Proceedings of the National Academy of Sciences of the United States of America 111:7176–84.

Petchey, O. L., M. Pontarp, T. M. Massie, S. Kéfi, A. Ozgul, M. Weilenmann, G. M. Palamara, F. Altermatt, B. Matthews, J. M. Levine, D. Z. Childs, B. J. McGill, M. E. Schaepman, B. Schmid, P. Spaak, A. P. Beckerman, F. Pennekamp, and I. S. Pearse. 2015. The ecological forecast horizon, and examples of its uses and determinants. Ecology Letters 18:597–611.

Powers, S. M., and S. E. Hampton. 2019. Open science, reproducibility, and transparency in ecology. Ecological Applications 29:1–8.

Read, E., M. Rourke, G. Hong, P. Hanson, L. Winslow, S. Crowley, C. Brewer, and K. Weathers. 2016. Building the team for team science. Ecosphere 7:1–9.

Wikle, C., and L. Berliner. 2007. A Bayesian tutorial for data assimilation. Physica D: Nonlinear Phenomena 230:1–16.