GE 585 - Ecological Forecasting and Informatics
Spring 2019

Time: MWF 10:10-11:00
Location: CAS 221

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

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)
- MA 115 or MA 213 or GE 375 or GE 516 or consent of instructor
  A statistics or modeling course that provided some exposure to basic probability concepts and distributions.

Recommended:

- Previous 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.

Technology:

Phones:
The use of phones in class is prohibited. This includes texting, email, an 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

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.

For additional tutorials and background see the Github instructions we maintain for the PEcAn project
https://pecanproject.github.io/pecan-documentation/master/git-and-github-workflow.html

Course Format & Outline:

In this course we will approach each topic 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)
1/23	Syllabus	Technology	Preface
1/25	Overview	Lecture	Chapter 1
1/28	The command prompt is my friend	Hands-on	1. R primer O: Google R tutorials O: Git/Github tutorials
1/30	Ecological Forecasting	Discussion	(Clark et al. 2001) (Dietze et al. 2018)
2/1	From models to forecasts	Lecture	Chapter 2
2/4	Logistic Growth	Hands-on	2. From Models to Forecasts
2/6	Predictability	Discussion	(Petchey et al. 2015) O: (Dietze 2017)
2/8	Data, large and small	Lecture	Chapter 3 O: Data One Best Practices
2/11	Tools for big data	Hands-on	3. Big Data
2/13	Open Science	Discussion	(Powers and Hampton 2019)
2/15	Informatics of Model-Data Fusion	Lecture	Chapter 4
2/19 Tues	Workflows	Hands-on	Pair Coding
2/20	Intro to Bayes	Lecture	Chapter 5 O: (Ellison 2004) O: Bayesian Regression
2/22	Invasive species	Discussion	(Ibanez et al. 2014)
2/25	BUGS/JAGS	Hands-on	JAGS Primer
2/27	Expert Elicitation	Discussion	(Morgan 2014)
3/1	Characterizing Uncertainty	Lecture	Chapter 6 O: Fitting Uncertainties O: Hierarchical Bayes
3/4	State-space models	Hands-on	Chapter 8 6. State Space
3/6	Biodiversity	Discussion	Chapter 7
3/8	Fusing data sources	Lecture	Chapter 9
	SPRING BREAK		
3/18	Data-Fusion	Hands-on	8. Tree Rings O: (Clark et al. 2007)
3/20	Fisheries	Discussion	Chapter 10
3/22	Propagating Uncertainty	Lecture	Chapter 11 O: Uncertainty Partitioning
3/25	PEcAn	Hands-On	PEcAn Tutorial
3/27	Carbon	Discussion	Chapter 12
3/29	Data Assimilation: Analytical	Lecture	Chapter 13 O: (Wikle and Berliner 2007)

4/1	Kalman Filter	Hands-on	9. Kalman Filter
4/3	Land Cover & Disturbance	Discussion	(Daniel et al. 2016)
4/5	Data Assimilation: Monte Carlo	Lecture	Chapter 14 O: (Evensen 2009)
4/8	Ensemble KF	Hands-on	10. Particle Filter
4/10	Epidemiology	Discussion	Chapter 15
4/12	Assessing Model Performance	Lecture	Chapter 16
4/15	NO CLASS		Patriot's Day
4/17	Benchmarks	Discussion	(Luo et al. 2012)
4/19	Model Assessment	Hands-on	11. Model Assessment
4/22	Scenarios & Decision Support	Lecture	Chapter 17
4/24	Stakeholder "Role Playing" exercise	Hands-on	Activity
4/26	Decision Support	Discussion	(Memarzadeh and Boettiger 2019, Miller et al. 2019)
4/29	Final Thoughts	Lecture	Chapter 18
5/1	Final projects	Hands-on	
5/7	FINAL	Presentation	9:00am – 11:00am

Grading:

Hands-on activities	4.0 points each	48
Discussions	2.5 points each	30
Final Project	22 points	22
		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:

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 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.

Hands-on Activities

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 **emailed to the instructor by the start of class the following week**.

Research Project:

The goal of the final research product is to generate an operational forecast for a specified ecosystem state. At the start of the project you will begin with an uncalibrated process model that could be informed by two or more publicly available data streams. You will assess and quantify the sources of uncertainty that contribute to the forecast, calibrate and validate the model against training data, 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. Specific details of the projects will be posted on the course website by Feb 1 and students are strongly encouraged to work on the project throughout the semester as they are introduced to each topic.

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

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**.

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.

Daniel, C. J., L. Frid, B. M. Sleeter, and M. J. Fortin. 2016. State-and-transition simulation models: a framework for forecasting landscape change. Methods in Ecology and Evolution 7:1413–1423.

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.

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, A. 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.

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