

# Data Diagnostics: Detecting and Characterizing Deterministic Structure in Time Series Data

ABE 6840, Fall 2022

Monday 2<sup>nd</sup>-4<sup>th</sup> Period (8:30-11:30)

## Instructor

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Office Hours (Open: online/Zoom)

## Venue

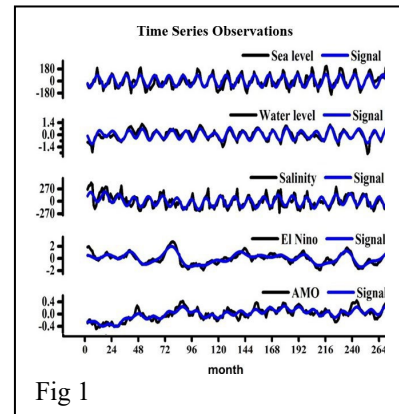
In class

## Prerequisites

While there are no formal prerequisites, experience working with **R** programming language is helpful. Students without **R** experience are strongly advised to take one of several available online introductory tutorials to familiarize themselves with programming basics in **R**.

## Course Overview

The scientist Clifford Stoll observed that: “Data is not information, Information is not knowledge, Knowledge is not understanding, Understanding is not wisdom.” Time series data provide an essential portal to understanding the systematic behavior of real-world processes. These data may be ‘observational’ (e.g., collected with direct/remote sensing instruments), ‘experimental’ (e.g., output of lab experiments), or ‘simulated’ (i.e., model output). However, ‘data is not information’ until it has been analyzed for behavioral patterns, and ‘information is not knowledge’ until detected patterns are explained with theory. The objective of ABE6840 is to cross the portal from data to information—to detect behavioral patterns in data that students can then explain with science from their disciplines. Crossing this portal is challenging because time series data often exhibit an irregular appearance that conceals behavioral patterns from a cursory inspection (Fig 1). The conventional view is that irregularity in complex data derives from the stabilizing responses of biophysical processes to exogenous random shocks. However, mathematical breakthroughs demonstrate the surprising result that irregular and apparently-random observed behavior can emerge endogenously in deterministic nonlinear dynamic systems. Several recent papers detect these dynamics in real-world environmental systems. Detecting the source of irregularity in data is pivotal, for example, to understanding how to most effectively manage particular real-world dynamic systems: Can we rely on a system to self-correct in response to outside shocks, or must we take human-in-the-loop corrective actions?



ABE6840 introduces students to Nonlinear Time Series Analysis (NLTS)—a collection of methods recently developed to detect and reconstruct deterministic nonlinear dynamics concealed in complex real-world and experimental data, and to detect causality among system covariates. Although NLTS is not yet widely used in applied science, engineering, and social science disciplines (and thus may well be unfamiliar to most students), it is firmly established in high-impact science, physics, and mathematical statistics journals.

## Course Objectives/Outcomes

The objective of ABE6840 is to put NLTS methods within the operational reach of students in engineering and the applied sciences. After taking this course, students should be able to:

- Apply *signal processing techniques* to detect behavioral patterns in complex time series data
- Apply *phase-space reconstruction* techniques to reconstruct dynamics driving detected patterns
- Apply *convergent cross mapping* techniques to empirically detect causality in dynamic systems

## Course Format

Course materials are online at the ABE6840 CANVAS site. Lectures take the form of six written modules that build up an analytical sequence of NLTS methods. Each module introduces a method, provides (and explains) **R** code to run the method, and applies the method to a real-world time series. Each module is accompanied by a homework assignment designed to give students hands-on experience with applying the method/code to analyze other real-world time series available on CANVAS. Modules 2-6 each require two weeks. During the first week, students work through the module. This requires that students thoroughly digest the material, and also run the application on their own laptops. During the second week, students complete the homework assignment for the module. Homeworks become more extensive each module as additional methods are added to the analytical sequence. In the final project, students apply the entire sequence of NLTS methods to analyze two time-series records of their choice, and provide a written report of the results. Students may select the time series from among those stored on the CANVAS site, or from their research.

## Course Schedule

Aug 29-Sep 2	Module 1: Getting Started
Sep 5	Holiday
Sep 12-Sep23	Module 2: Fourier Analysis and Time-Delay Embedding
Sep 26-Oct 7	Module 3: Singular Spectrum Analysis
Oct 10-Oct 21	Module 4: Phase Space Reconstruction
Oct 24-Nov 4	Module 5: Surrogate Data Analysis
Nov 7-Nov 18	Module 6: Convergent Cross Mapping
Nov 21-Dec 2	Complete Final Project
Dec 5	Present Final Project in-class

## Assignments and Grading

- Assignments must be turned into the ABE6048 CANVAS site by 5 pm on the due date.
- **Students may consult with each other on homeworks and the final project but must do their own work.**
- Requirements for make-up assignments follow university policies found at:  
<https://catalog.ufl.edu/ugrad/current/regulations/info/attendance.aspx>

Homework	Assigned	Due	Points			
Module 1	29-Aug			A 500-465	A- 464-450	
Module 2	12-Sep	23-Sep	30	B+ 449-435	B 434-415	B- 414-400
Module 3	26-Sep	7-Oct	40	C+ 399-385	C 384-365	C- 364-350
Module 4	10-Oct	21-Oct	50	D+ 349-335	D 334-315	D- 314-300
Module 5	24-Oct	4-Nov	60	F < 299		
Module 6	7-Nov	18-Nov	100			
Final Project	7-Nov	5-Dec	<u>220</u>			
			500			

### Students Requiring Accommodations

Students with disabilities who experience learning barriers and would like to request academic accommodations should connect with the disability Resource Center by visiting <https://disability.ufl.edu/students/get-started/>. 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. Guidance on how to give feedback in a professional and respectful manner is available at <https://gatorevals.aa.ufl.edu/students/>. 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 <https://ufl.bluera.com/ufl/>. Summaries of course evaluation results are available to students at <https://gatorevals.aa.ufl.edu/public-results/>.

### In-Class Recording

Students are allowed to record video or audio of class lectures. However, the purposes for which these recordings may be used are strictly controlled. The only allowable purposes are (1) for personal educational use, (2) in connection with a complaint to the university, or (3) as evidence in, or in preparation for, a criminal or civil proceeding. All other purposes are prohibited. Specifically, students may not publish recorded lectures without the written consent of the instructor.

A “class lecture” is an educational presentation intended to inform or teach enrolled students about a particular subject, including any instructor-led discussions that form part of the presentation, and delivered by any instructor hired or appointed by the University, or by a guest instructor, as part of a University of Florida course. A class lecture does not include lab sessions, student presentations, clinical presentations such as patient history, academic exercises involving solely student participation, assessments (quizzes, tests, exams), field trips, private conversations between students in the class or between a student and the faculty or lecturer during a class session.

Publication without permission of the instructor is prohibited. To “publish” means to share, transmit, circulate, distribute, or provide access to a recording, regardless of format or medium, to another person (or persons), including but not limited to another student within the same class section. Additionally, a recording, or transcript of a recording, is considered published if it is posted on or uploaded to, in whole or in part, any media platform, including but not limited to social media, book, magazine, newspaper, leaflet, or third party note/tutoring services. A student who publishes a recording without written consent may be subject to a civil cause of action instituted by a person injured by the publication and/or discipline under UF Regulation 4.040 Student Honor Code and Student Conduct Code.

### 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 Conduct Code (<https://sccr.dso.ufl.edu/process/student-conduct-code/>) specifies a number of behaviors that are in violation of this code and the possible sanctions. If you have any questions or concerns, please consult with the instructor or TAs in this class.

### Commitment to a Safe and Inclusive Learning Environment

The Herbert Wertheim College of Engineering values broad diversity within our community and is committed to individual and group empowerment, inclusion, and the elimination of discrimination. It is

expected that every person in this class will treat one another with dignity and respect regardless of gender, sexuality, disability, age, socioeconomic status, ethnicity, race, and culture.

If you feel like your performance in class is being impacted by discrimination or harassment of any kind, please contact your instructor or any of the following:

- Your academic advisor or Graduate Program Coordinator
- Jennifer Nappo, Director of Human Resources, 352-392-0904, [jpennacc@ufl.edu](mailto:jpennacc@ufl.edu)
- Curtis Taylor, Associate Dean of Student Affairs, 352-392-2177, [taylor@eng.ufl.edu](mailto:taylor@eng.ufl.edu)
- Toshikazu Nishida, Associate Dean of Academic Affairs, 352-392-0943, [nishida@eng.ufl.edu](mailto:nishida@eng.ufl.edu)

### 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: <https://registrar.ufl.edu/ferpa.html>

### Campus Resources:

#### Health and Wellness

#### **U Matter, We Care:**

Your well-being is important to the University of Florida. The U Matter, We Care initiative is committed to creating a culture of care on our campus by encouraging members of our community to look out for one another and to reach out for help if a member of our community is in need. If you or a friend is in distress, please contact [umatter@ufl.edu](mailto:umatter@ufl.edu) so that the U Matter, We Care Team can reach out to the student in distress. A nighttime and weekend crisis counselor is available by phone at 352-392-1575. The U Matter, We Care Team can help connect students to the many other helping resources available including, but not limited to, Victim Advocates, Housing staff, and the Counseling and Wellness Center. Please remember that asking for help is a sign of strength. In case of emergency, call 9-1-1.

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

#### **Sexual Discrimination, Harassment, Assault, or Violence**

If you or a friend has been subjected to sexual discrimination, sexual harassment, sexual assault, or violence contact the [Office of Title IX Compliance](#), located at Yon Hall Room 427, 1908 Stadium Road, (352) 273-1094, [title-ix@ufl.edu](mailto:title-ix@ufl.edu)

#### **Sexual Assault Recovery Services (SARS)**

Student Health Care Center, 392-1161.

**University Police Department** at 392-1111 (or 9-1-1 for emergencies), or <http://www.police.ufl.edu/>.

## Academic Resources

**E-learning technical support**, 352-392-4357 (select option 2) or e-mail to Learning-support@ufl.edu.  
<https://lss.at.ufl.edu/help.shtml>.

**Career Resource Center**, Reitz Union, 392-1601. Career assistance and counseling;  
<https://career.ufl.edu>.

**Library Support**, <http://cms.uflib.ufl.edu/ask>. 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.  
<https://teachingcenter.ufl.edu/>.

**Writing Studio, 302 Tigert Hall**, 846-1138. Help brainstorming, formatting, and writing papers.  
<https://writing.ufl.edu/writing-studio/>.

**Student Complaints Campus**: <https://sccr.dso.ufl.edu/policies/student-honor-code-student-conduct-code/>; <https://care.dso.ufl.edu>.

**On-Line Students Complaints**: <http://www.distance.ufl.edu/student-complaint-process>.