**Instructor:** Ray Huffaker, Agricultural and Biological Engineering, University of Florida (rhuffaker@ufl.edu).

**Course Duration:** 4 hours/day x 5 days

**Prerequisites:** Elementary statistics, differential calculus, matrix algebra, programming basics in R.

**Content**: This short course is about 'getting to know your data'. Crowley (2015) explains the importance of knowing your data as follows:

> "Once data are in the computer, the temptation is to rush straight in to statistical analysis. This is exactly the wrong thing to do. You need to get to know your data first. [I]f you do know what your data look like, then you will not know what model to select to fit to the data or whether the assumptions of your intended model are met by the data" (Statistics: An Introduction Using R ($2^{nd}$ edn), Wiley, United Kingdom, p. 31).

The first thing we notice about time series data is that it is often highly variable with a random appearance. Observed volatility is commonly attributed to external random shocks to real-world systems that are otherwise stable. If we believe this, then we select a linear-stochastic modeling approach. However, breakthroughs in nonlinear dynamics teach us that highly complex dynamics also can emerge from astoundingly simple deterministic nonlinear dynamic models. The implication is that observed volatility may be due to the deterministic (endogenous) operation of real-world dynamic systems and not to external random forces. If we believe this, then we select a deterministic nonlinear-dynamic modeling approach.

This short course is about replacing presumption with data diagnostics to make an informed decision about the right modeling approach to pursue. An informed decision is crucial for models intended to inform public policy. Oreskis et al. (1994) recommend that "where public policy and public safety are at stake, the burden is on the modeler to demonstrate the degree of correspondence between the model and the material world it seeks to represent…" (Verification, validation, and confirmation of numerical models in the earth sciences, *Science* 263, p. 644). The European Union formally audits models used in public policy. It is good practice to model like you expect to be audited…to have a compelling reason for every decision. This short course will show you how to use data to make a compelling case for the legitimacy of your model.

**Objective:** The major objective is to give participants hands-on experience and confidence in employing nonlinear data diagnostic techniques in applied research. Consequently, the short course takes a 'workshop' approach to learning. We will cover the background information required to understand how and why diagnostic methods work. We will run these methods using R together in class to analyze several economic and biophysical time series. This requires that participants bring their personal laptops to class.

## Prospective Topics

### 1. Why Study Nonlinear Time Series Analysis?

- A Diagnostic Strategy for Data-Driven Discovery of Real-World Dynamics
- The Contribution of NLTS Diagnostics to Theoretical Modeling
- Caveats in Application

### 2. Data Pre-processing

- Regular Behavior of Linear ODE models
- Noisy Linear Dynamics
- Signal Processing:  Singular Spectrum Analysis
- Testing for Nonlinear Nonstationarity in Times Series Data
- Phase Space Reconstruction and Nonlinear Prediction
- Endogenous Complexity with Nonlinear Dynamics

### 3. Surrogate Data Testing

- Surrogate Data Algorithms
- Discriminating Statistics
- Rank Order Statistics

### 4. Nonlinear Causality Analysis

- Convergent Cross Mapping
- Extended (Delayed) Convergent Cross Mapping

### 5. Phenomenological (Data-Based) Modeling

- Components of a Phenomenological Model
- Approximation of Derivatives with Finite Differences
- Multivariate Polynomial Expansions
- Estimating System Coefficients: Regularized Regression Methods
- Solution of Phenomenological Model
- Phenomenological Model Extracted from Three Observed Variables
- Phenomenological Model Extracted from a Single Observed Variable