Course Announcement for Spring 2019:

MAT 451: Mathematical Modeling
APM 598: Topic: Mathematical Modeling

"Mathematical Modeling of Global Environmental Change"

Title/Section: MAT 451 (22788): Mathematical Modeling
APM 598 (31184): Topic: Mathematical Modeling
Instructor: Steffen Eikenberry (Office: WXLR 441)
Email: seikenbe@asu.edu, steffen.eikenberry@asu.edu
Logistics: Time: MW 3:05-4:20, Classroom: Tempe DISCVRY 120

Course Description and Topics: Earth has undergone dramatic environmental change throughout its history, yet environmental conditions have remained within the narrow range required for the continuous existence of life for roughly four billion years, and, more recently, for human agricultural civilization. The latter is itself profoundly altering the global environment at an accelerating pace, such that Earth has arguably entered a new geologic era dominated by humans, the *Anthropocene*. Hence, this course will entail an historically motivated survey of applications of mathematical modeling to large-scale environmental change and human activity.

Specific topics will include modeling climate variability, including paleoclimate and possible tipping points under human-caused global warming; ozone-depleting substances; global energy, material, and nutrient fluxes; peak oil; lifecycle analysis and consumption-based accounting of environmental harm; and limits to growth, delay effects, and the concepts of overshoot and planetary boundaries.

Course will also emphasize basic spatial data analysis and visualization in MATLAB, descriptive statistics, and modeling in MATLAB. Key data sources will be identified. Emphasis on primary research literature, and student projects and presentations.

Prerequisites: Knowledge of ordinary differential equations-based modeling (at least at level covered in MAT 275), and a good working knowledge of MATLAB are strongly recommended. However, interested students from other fields with less math background are still encouraged to seek instructor permission.

Textbook: Primary course material will include lecture notes and selected research articles, with a strong emphasis on the primary literature. Some material may also be based on the following supplemental texts:

- *Optional textbook:* S. E. Eikenberry. A Fair Share: Doing the Math on Individual Consumption and Global Warming. 2018.
- R. T. Pierrehumbert. Principles of Planetary Climate. Cambridge, 2010.
- M. K. Heun, M. Carbajales-Dale, & B. R. Haney. Beyond GPD: National Accounting in the Age of Resource Depletion. Springer, 2015.

Evaluation: Grade will be based upon several homework sets that will generally involve reading the primary literature and MATLAB programming, a mini literature review, and final course project and presentation.

Undergraduate/Graduate credit: Course may be taken either for undergraduate (MAT 451) or graduate (APM 598) credit. Those taking the course for graduate credit will be expected to complete slightly more advanced homework sets and will be held to a higher standard on the literature review and project.

Tentative Schedule of Topics (Subject to Change)

Weeks 1 -4: Introduction, the Holocene and Anthropocene, and climate fundamentals.

- Planetary boundaries, the "Great Acceleration," major environmental shifts in last million years.
- Paleoclimate, brief history of scientific thought on climate
- Charner Report and concept of equilibrium climate sensitivity (ECS)
- GHG perturbations: GWP and GTP metrics
- Tipping points and nonlinear feedbacks
- Global circulation models (GCMs)
- Intro to GIS visualization in MATLAB
- Ozone-depleting substances and the Montreal Protocol

Week 5: Energy as master resource

- Major energy carriers
- Energy conversion: Heat engines, concept of primary energy
- Energy return on investment (EROI); EROI for major energy sources and historical trends

Weeks 6-8: Limits to growth

- Historical roots from Malthus, Darwin, and Jevons
- Nutrient/Resource-limited growth models
- Peak oil theory and M. King Hubbert
- Limits to growth and the Club of Rome
- Economic modeling

Weeks 9-10: Agriculture

- History of agriculture as basis of civilization: climate, land, sociopolitical interaction
- Law of the Minimum: Limiting nutrients
- Global nutrient fluxes
- Food-Energy-Water Nexus

Weeks 11-12: Lifecycle Analysis

- Concept of consumption-based accounting
- Process-based modeling
- Trade-linked, consumption-based economic input-output (EIO) analysis

Week 13: Ecological Footprint Analysis

- Material and energy footprint of cities
- Planetary boundaries and "safe operating spaces"

Weeks 14-15: Biodiversity

- History; concept of defaunation
- Ecological niche modeling
- Climate and infectious disease
- Harvesting models