# Quantitative Methods in the Geosciences
# 21-460-375
## Fall 2018 Syllabus

***Instructor*:** Dr. Kristina Keating
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***Office*:** Smith Hall 139
***Office Hours***: Monday 11:00am-12:00pm
***Meeting Time*:** Mon 1:00pm-3:50pm (lecture); Wed 11:30am-2:20pm (lab)

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**Course Description**
This course provides an overview of the basic quantitative and computing methods used to understand geoscience datasets. The student will gain confidence in the quantitative interpretation of geoscience datasets and acquire skills that are required to fully understand many earth and environmental science subject areas. Concepts covered include [1] plotting and visualizing geoscience data, [2] basic data analysis using Excel and Matlab, [3] linear regression and curve fitting models to geoscience datasets, [4] krigging methods, [5] time series analysis. Examples illustrating each concept will be drawn from the geosciences.

**Learning objectives**

The primary learning objective of this course is also a key learning objective for the environmental science and geology major programs offered by the department of earth and environmental sciences: *Acquisition of quantitative skills relevant to the geosciences and environmental sciences through the collection, analysis, and synthesis of scientific data*

Course specific learning goals that fall under this department level goal include:

- Mastery of basic numeric manipulation and literacy
- Mastery of basic processing, curve fitting and graphical analysis of data using Excel and Matlab
- Ability to apply simple models to geoscience datasets and estimation of model parameters, along with uncertainty assessment
- Familiarity with basic time series analysis methods for extracting geoscience information from time series datasets

**Schedule (subject to change)**

Units 1 and 2 are designed to introduce fundamental basic quantitative skills. Units 3 to 7 are directed at gaining expertise and confidence in Excel and Units 8 to 12 are directed at gaining expertise and confidence in MATLAB. These are two of the most extensively used tools for quantitatively investigating geoscience data. Units 13 and 14 will use these tools to interpret

different aspects of data. In each unit we will use example datasets from a broad range of the geosciences.

**Unit 1: Introduction**:

- Why do we need quantitative analysis of geoscience data?
- Examples from scientific literature and popular media (e.g. the hockey stick curve; bar graphs).
- Recognition of simple functions: exponential growth/decay, log growth, lines, polynomials, trig functions.
- Functional notation.
- Approaches for problem solving (what are the data, what are the unknowns, what are the constraints, drawing a diagram, etc).
- Identifying independent variables, dependent variables and model parameters

**Unit 2: Basic number skills**:

- Solving equations for unknowns.
- Understanding units of measure common in the geosciences.
- Defining units appropriate for a problem.
- Understanding significant figures.
- Scientific notation.
- Rounding numbers and precision versus accuracy.
- Converting units.
- Making estimates/back of the envelope calculations.

**Unit 3: Introduction to the spreadsheet I**

- Basic Excel skills (entering data, loading data, making calculations, plotting two variables, different types of plots).

**Unit 4: Introduction to the spreadsheet II**

- Plotting in excel.
- Basic excel functions (average, sum, stdev, var, max, min, count, countif, abs, sqrt)
- Verbal descriptions of numerical relations.
- Basic line fitting

**Unit 5: Data collection and analysis I: basic statistics.**

- Trendline fits
- Basic analysis of trendline fits
- Data and predicted data
- Residuals, sum squared residuals, sum squared total, R-squared value
- Regression function

**Unit 6: Data collection and analysis II: basic statistics.**

- Histograms
- Histogram function in excel
- Using histograms to analyze residuals.

**Unit 7: Data collection and analysis I: basic statistics.**

- Solver in excel
- Fitting a Gaussian distribution to a histogram of residuals.

**Unit 8: Introduction to Matlab: Basic Matlab skills:**

- Entering data.
- Basic plots and plotting data.
- Manipulating data.

**Unit 7: Data collection and analysis I: basic statistics.**

- Assessing data quality.
- Calculating means and standard deviations and probability density functions.
- Creating and understanding histogram.

**Week 8: Data collection and analysis II: Interpreting results.**

- Developing logical conclusions based on numerical relations.
- Understanding sources of error and error propagation rules.
- Understanding assumptions and how that affects numerical relations.
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**Unit 9: Numerical models in the geosciences:**

- The difference between data (inputs) and model parameters (unknowns).
- Understanding fluxes and rates.
- Developing flow charts.

**Unit 10: Predicting geoscience data with a model**:

- The 'forward' problem

**Unit 11: Estimating model parameters from geoscience observations**:

- the 'inverse' problem

**Unit 12: Time series analysis:**

- Extracting the important information from long geoscience datasets.

**Unit 13: Time-frequency analysis:**

- Analyzing the frequency content of time series data and what it means.
- Identifying wave characteristics (wavelength, period, amplitude, frequency).
- Recognizing periodic phenomena (in time and space).

**Unit 14: Interpolation, kriging and contouring spatial geoscience data**:

- Developing a meaningful interpolation.
- Understanding kriging artifacts.

**Texts:**

There is no required text for this book as all material for this course (both lecture and lab) will be constructed by the Professors using examples of their own work in the geosciences, along with the extensive resources developed by the Science Education Resource Center (SERC) at

Carlton College in recognition of the need to improve quantitative training in undergraduate geosciences (http://serc.carleton.edu/quantskills/about.html).

## Grading

The breakdown for the grading is as follows.

- *Take home assignments/lab write-ups*: 30%
- *2 Midterms*: 25%
- *Final*: 25%
- *Quizzes:* 10%
- *Participation:* 10%

Grading information

- *Take home assignments*: –Weekly assignments are due in class one week after the assignment was given out. All assignments should be handed in electronically via blackboard. Unless otherwise stated, **only assignments that are returned as a single pdf document will be accepted.**
  *** NO LATE ASSIGNMENTS WILL BE ACCEPTED ***
  As I recognize that at times there are extenuating circumstances that will prevent you from being able to complete your assignment on time, the two lowest assignment grades will be dropped.
- *2 Midterms*: in-class, closed-book format; all exams will be cumulative.
  ***Midterm 1: Wednesday October 3rd***
  ***Midterm 2: Wednesday November 14th***
- *Final*: in-class, closed-book format; all exams will be cumulative – time determined by Rutgers Exam Schedule.
- *Quizzes:* in-class, closed-book format; quizzes are not cumulative – once per week at the beginning of the lecture. No make-up quizzes will be given, but the two lowest quiz grades will be dropped.
- *Participation:* Students are expected to participate in class and will be graded according to their in class participation. Participation grades will be given for (1) participating in class discussions, (2) participating in small group discussions, and (3) in class answers to group assignments.

## Attendance Policy

Attendance is not mandatory for this class, however, missing classes will result in reduced quiz grades, as no make-up quizzes will be given, and a reduced participation grade. If you anticipate that you will have an extended absence from class due to an unforeseen circumstance, please make an appointment to speak with me outside of class to discuss your options.

## Student responsibilities

- *Notes*: No notes will be handed out and students are expected to take careful notes. This format was chosen because it has been shown that students learn and retain information better when taking hand written notes in class (as opposed to notes on a computer or not

taking notes at all.) If you would like to discuss note taking strategies then let me know and we can either do so in class or during my office hours.

- *Respect*: Out of respect for their peers and their professor, students should arrive on time and should not wander in and out of class during the lecture. Phones should be turned off for the duration of class. Computers in class should only be used for course-related activities. Students are expected to listen to their peers or their professor during class and not interrupt. Any student found disrupting class will be asked to leave for the duration of the lecture. Students are expected to everyone in the class (professor, TA, fellow students) respectfully; disrespectful behavior will not be tolerated and will be addressed immediately.
- *"Home" work:* The problems and labs assigned in this class are designed to help improve student problem solving abilities and to encourage independent learning. As such, to answer some problems students may be required to do research beyond what is directly taught in class. To facility this approach, students are strongly encouraged to take advantage of the faculty office hours and to work in groups. Occasionally, reading assignments will be given out before class. When this is the case students are expected to come to class having read the reading material and to be prepared to discuss it. As with most undergraduate level courses, it is expected that each student will spend approximately three hours working on course material (assignments and studying) outside the classroom for every one hour spent in the classroom.

**Email Policy**

Emails sent to the professor should be formatted properly (the proper format will be discussed in class). Emails not sent with the proper format will not be answered. Expect at least 24 hours between sending an email and receiving a response. Emails will only be answer Monday through Friday. Note, that this means that if you need help with an assignment and would like to contact me to arrange a time to meet, you need to send an email about that at least two days before the assignment is due.

**<u>Other Important Information</u>**

**Americans with Disabilities Act Statement**: If you need accommodations because of a documented disability, contact the Disabled Student Services Office on x5300

**Academic Honesty Policy**: Cheating in any form will not be tolerated. The first occurrence of any of this behavior will result in a grade of "F".