COMPUTATIONAL METHODS IN EARTH SCIENCES

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1. Course description

The objective of this course is to introduce students to a range of ways in which computers can help them analyze and process data, translate ideas and conceptual models into computer simulations, visualize their findings, and work alone or in teams to address research questions. Students will be introduced to the Python programming language, which is easy to learn and used broadly across the geosciences. They will work with real data sets and write models to understand systems that are of relevance to their research.

2. Required materials

- Bring a laptop computer to class; please email the instructor if this is a problem
- Textbook, *Think Python: How to Think Like a Computer Scientist*: PDF and HTML available at `http://www.greenteapress.com/thinkpython/`

3. Learning goals

This course will be broken into four modules:

(1) An introduction to the Python programming language
   - Commands in Python
   - Imperative and object-oriented programming
   - Software architecture and (re)usability

(2) Working with data sets
   - Text files, binary data files, spreadsheets, and specialized formats (e.g., NetCDF)
   - Plotting data
   - Basic data analysis
   - Optional: Introduction to GIS applications with Python

(3) Working with models
   - Introduction to types of models
   - Differential equations review: simple analytical solutions, Taylor series approximations, and numerical solutions
   - Matrix algebra to solve systems of differential equations: applying the finite difference method

(4) Projects
   - Build software that will assist you in a topic of your choosing (ideally related to your research)
   - Learn how to use version-control software and appropriate licensing for collaborative work
   - Integration of data and models is encouraged
   - Present results at the end of the semester

4. Evaluation

Students taking the course for a grade will be evaluated on the basis of their contribution to the final project. This will include:

- Participation and course-related work through the semester (35%)
- Final project code (50%)
- Final project presentation (15%)

5. Schedule

06 May, 14:00–17:00: Haus 27, Raum 2.36
Programming: philosophy, problem-solving, and basic volcabulary
Reading: Chapters 1–2

- **Before class:** Install Python Python 2.7.X on your computer. Please email the instructor if you have problems.
  - Windows and Mac: Python(x,y) is the most open-source distribution, but Anaconda is the easiest to download and use. See `http://docs.continuum.io/anaconda/install.html`
  - Linux: "apt-get install python-numpy python-scipy python-matplotlib ..." or equivalent from your pacakage manager
- **Before class:** Also install a nice programming editor like TextWrangler (Mac), Notepad++ (Windows), or gedit (every platform)
- Editing and running Python: text editors, Spyder, iPython
- Programming syntax
- Variables and types
- Loops and statements
- Introduce version control software (goal: download course materials with git)
- Exercise: Randomly-walking particle (or something else fairly simple that applies these skills)

08 May, 08:15–12:00: Haus 25, Raum D2.01
Classes, functions, modules, plotting

- **Before class:** Version control software installed and working
- Introduction to namespaces
- Python modules (built-in)
- Functions
- Classes and object-oriented programming
- Using a pre-built module: Matplotlib for plotting
- Exercise: Writing your own class for a block of rock/soil

13 May?, 8:15AM–12PM?
Mathematical methods review; doing math in Python

- **Before class:** (Maybe) math review worksheet
- Derivatives and differential operators
- Integrals and numerical methods for integration
- Vectors, matrices, and arrays
- Dot products, cross products
- Forward difference discretization of differential equations
- Exercise: array and matrix operations: solving heat transport through your soil block from the week before

22 May, 8:15AM–12PM
Working with data

- **Before class:** Bring a set of data you want to analyze; email the instructor to ensure that your data format will be covered
- Text files
- Spreadsheets
- Binary files
- NetCDF files
- Geospatial data (if we get this far)
- Exercise: using what we have learned for each of your data sets

02, 03, 09 or 10 June?, 8:15AM–12PM?
Probability theory; integrating data sets and models

- Basic lecture: Modeling and finite difference methods Part 1
- **Guest lecture:** Crystal Ng: Probability in the geosciences
- Modeling hillslope evolution

12 June
Finite Difference Methods – the better way

19 June
Final projects – start of work

****INSTRUCTOR IN THE FIELD IN ARGENTINA 23 JUNE – 30 JULY; WILL DO HIS BEST TO ANSWER EMAILS RELATED TO FINAL PROJECTS. SO GET STARTED REALLY EARLY!****

If time allows – otherwise those seeking credit will just submit via email
Final projects – presentations