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GEO111 – NUMERICAL SKILLS IN GEOSCIENCE

UNIVERSITY OF CALIFORNIA, RIVERSIDE / DEPARTMENT OF EARTH SCIENCES
2015/6

http://www.seao2.info/teaching.html

First printing, September 2016

Course Introduction

GEO111 will provide an introduction to computer programming and numerical modelling for Earth and Environmental Science problems. It will provide a chance to learn a computer programming language and all the elements that constitute it, including concepts in number bases and types, logical constructs, debugging, etc. The course will develop programming skills step-wise, applying them at each point to practical questions and outcomes, such as data processing and visualization. How complex environmental processes can be encapsulated and approximated, and numerical models thereby constructed, will be illustrated. Guided opportunities will be provided to build a 'DIY' climate model and in doing so, further develop programming and modelling skills at the same time as reinforcing basic concepts in climate dynamics through practice in addition to theory.

The cumulating objectives of the course are to:

1. develop an understanding of how computers and the internet work and hence foster a critical understanding of modern technology,
2. provide hands-on training in how computer programs are written and numerical models constructed, and
3. develop both general (transferable) as well as specific numerical and analytical skills applicable to the Earth and Environmental Sciences.

The associated learning goals are firstly; to provide, through hands-on practical exploration, factual knowledge and an understanding of:

- Number bases, how computers work plus computer programs and their basic building blocks. (Learning Outcome 2).
- Numerical models and the representation of time. Construction and application of a variety of models spanning box models of biogeochemical cycles and population dynamics, through 1D reaction-diffusion models of surface Earth processes, to 3D gridded global models. (Learning Outcomes 1 and 2).
- The Greenhouse effect and basic climate feedbacks. (Learning Outcome 1).
- Awareness of how webpages and the internet work. (Learning Outcomes 2 and 4).
- The use of numerical models in addressing scientific questions and testing hypotheses as well as the limitations of numerical models. (Learning Outcomes 2 and 4).

and provide transferable skills in

- Written communication and presentation. (Learning Outcome 3).
- Problem solving and logical analysis, fault-finding. (Learning Outcomes 4 and 5).
- Computer programming. (Learning Outcomes 2 and 4).

Course logistics

Format

The weekly format of the Class is: one 1-hour lecture, together with one 3-hour computer practical session, plus a 2-hour interactive lecture/discussion session of worked problems and examples. The computer practical class is the central element, and will consist of structured exercises leading step-by-step through the components of computer programming and numerical model construction, debugging, and testing, plus applications to common geosciences problems. The lecture starting each week will outline the basics and introduce the key concepts of the week. The purpose of the 2-hour lecture/discussion session ending the week is to ensure all the concepts are understood and misconceptions resolved and will be a mix of presentation and worked-through examples, plus questions and discussion.

Timetable

Assessment

The course will be assessed as follows:

- Midterm paper – 50%
- Finals paper – 50%

The mid-term paper will be w written exam, consisting of a mixture and multiple choice and short-answer format question. its purpose is to test basic knowledge of computers and programming, plus general concepts and basic commands in MATLAB. The testable content comprises the material covered in the lectures and lab sessions (in weeks #1-5). The exam will be 2 hours long. The mid-term paper will constitute 50% of the total assessment of the course.

The Finals paper will be based upon the development and application of a computer model written in MATLAB and will be presented in the form of a science paper describing the model, its evaluation, application to a specified science question, plus discussion of model caveats and suggestions for future improvements. The scope of the model exercise will be somewhat restricted with a short menu of possible choices, but with considerable flexibility in terms of exactly what is done and explored with it (i.e. there is some slightly possibility of actually having fun!). This will constitute the remaining 50% of the total assessment of the course.

	Monday am (1)	Monday am (2)	Friday pm
WEEK	***Lecture A*** ***08:10-09:00*** ***GEOL 1444***	***Computing lab*** ***09:10-12:00*** ***Watkins 2101***	***Lecture B*** ***14:10-16:00*** ***Watkins 2101***
19 / 23rd Sept.			**Introduction to the course** [Chapter 0] Format and content of the course. Office hours. Overview of course assessment.
26 / 30th Sept.	**Computing '101' #1** [Chapter 1] Basic constituents and functioning of computers. Computer operating systems, programs, and software. Compiled and interpreted languages. Introduction to MATLAB.	**Lab-based exercises** [Chapter 2] MATLAB basics, including variables and matrixes, data I/O. Data processing in MATLAB. Basic statistics." Basic plotting and data visualization.	**Worked examples & Q&A**
3 / 7th Oct.	**Fundamentals of computer programming** [Chapter 3] Bases, logic and logic gates. Loops and conditionals. Subroutines and functions.	**Lab-based exercises** [Chapter 3] Sub-programs and functions. Code de-bugging practice.	**Worked examples & Q&A**
10 / 14th Oct.	**Algorithms and problem-solving** [Chapter 6] Algorithms and numerical techniques. Search and sort algorithms. Programming best practice and debugging.	**Lab-based exercises** [Chapter 6]	**Worked examples & Q&A**
17 / 21st Oct.	**Data visualization** [Chapter 5]	**Lab-based exercises** [Chapter 5] 2-D ploting and interpolation. Re-gridding. Data binning and histograms. Accessing and visualizing netCDF format data.	**Worked examples & Q&A**
24 / 28th Oct.	**Computing '101' #2** [Chapter 4] How the internet 'works'. Computer networks. Web pages and basic html. Program GUIs.	**Lab-based exercises** [Chapter 4] Building a MATLAB GUI.	***MIDTERM EXAM***

Figure 1: Course schedule: weeks 1 through 5.

	Monday am (1)	Monday am (2)	Friday pm
WEEK	*Lecture A* *08:10-09:00* *GEOL 1444*	*Computing lab* *09:10-12:00* *Watkins 2101*	*Lecture B* *14:10-16:00* *Watkins 2101*
31 / 4th Nov.	**Introduction to numerical modelling [Chapter 7]** Time-stepping and integration techniques. Numerical stability and accuracy. Model code structure.	**0-D (box) modelling [Chapter 7]** Example: simple global radiocarbon box (reservoir) model.	**Worked examples & Q&A**
7 / 11th Nov.	**Global climate modelling #1 [Chapter 8]** Fundamental climate system processes and their representation in models. Surface energy budget and greenhouse gases. Heat capacity. Atmospheric transport.	**Lab-based exercises [Chapter 8]** Example: 0-D climate (energy balance) model.	***VETERANS DAY***
14 / 18th Nov.	**Global climate modelling #2 [Chapter 8]** Evaluation of numerical models. Model-data assessment. Numerical models in the literature, the work of the IPCC, and model 'inter-comparisons'.	**Lab-based exercises [Chapter 8]** Example: 1-D climate (energy balance) model.	**Worked examples & Q&A**
21 / 25th Nov.	**Biogeochemical modelling [Chapter 9]** Derivation and application of empirical relationships. Geochemical and biogeochemical models. Modelling ocean biogeochemical cycles. 1-D reaction-transport models.	**Lab-based exercises [Chapter 9]** Example: 1-D gas diffusion and consumption in soils.	***THANKSGIVING***
28 / 2nd Dec.	**Earth system modelling [Chapter 10]** Modelling feedbacks in the Earth system.	**Lab-based exercises [Chapter 10]** Example: 'Daisy World'.	**Worked examples & Q&A**

Figure 2: Course schedule: weeks 6 through 10.

Office Hours

There are no specific Office Hours, but rather an open invitation to drop by[1] (excluding Thursdays) and/or email[2] questions. Part of the purpose of the lab session on Fridays is to provide an opportunity for further clarification of the course material and to go through worked examples.

[1] My office is in the Geology building, room 464 (basement floor).

[2] andy@seao2.org

Course text

There is no one (or even two between them) commercial (published) course texts that covers both basic computer programming and numerical modelling at a suitable level, and certainly not in the context of MATLAB. Hence the reason for this *e*-book – to provide a 1-stop shop for a range of information and practical tutorials in useful and commonly used data manipulation and visualization, numerical techniques, and programming methodologies.

In conjunction with the course text (this document), a recommended (but note required) course textbook is *Matlab (Third Edition): A Practical Introduction to Programming and Problem Solving*[3], which provides a good general introduction to MATLAB and covers similar material to some of the course.

[3] Stormy Attaway. *Matlab (Third Edition): A Practical Introduction to Programming and Problem Solving*. Butterworth-Heinemann, 2013

For additional reading (on both MATLAB and numerical modelling), try:

- *The Climate Modelling Primer (4th Edition)*, by Kendal McGuffie and Ann Henderson-Sellers. Wiley-Blackwell (2014). ISBN: 978-1-119-94336-5.
- *Introduction to MATLAB (3rd Edition)*, by Delores M. Etter. Prentice Hall (2014). ISBN: 978-0133770018.
- *Mathematical Modelling of Earth's Dynamical Systems, A Primer*, by Rudy Slingerland and Lee Kump. Princeton (2011). ISBN: 978-0-691-14514-3.