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GEO111 – NUMERICAL SKILLS IN GEOSCIENCE

UBC – EARTH SCIENCES – 2015/6

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 different operating systems such as linux; of compiled languages such as FORTRAN, plus how webpages and the internet work. (Learning Outcome 2).
- 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 quantitative analysis together with logic and fault-finding. (Learning Outcomes 4 and 5).
- Computer programming. (Learning Outcomes 2 and 4).
- Effective internet use and website construction. (Learning Outcomes 2 and 4).

0.1 *Course logistics*

0.1.1 *Format*

The weekly format of the Class is: one 1-hour lecture, 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.

0.1.2 *Timetable*

0.1.3 *Assessment*

The course will be assessed as follows:

- Midterm paper – 40%
- Finals paper – 60%

(Part of the intention of the shorter Midterm assessment, being to provide critical feedback and guidance for the main Finals paper.)

The mid-term paper will consist of a computer model written in MATLAB to solve a specific problem, with the code to be handed in. The code will be accompanied by a 'user manual' for running the model code and conducting experiments. As part of the assessment, the code will be run to help judge the overall success of the program, with additional marking of the code itself (including structure and commenting). This will together constitute 40% of the total assessment of the course.

The Finals paper will be 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

	Monday am (1)	Monday am (2)	Friday pm
WEEK	Lecture A <i>08:10-09:00 -- GEOL 1444</i>	Computing lab <i>09:10-12:00 -- SPR 2101</i>	Lecture B <i>14:10-16:00 -- SPR 2101</i>
01 / 28th March	Introduction to the course Format and content of the course. Office hours. Overview of course assessment. Introduction to MATLAB and the 'command line'. Numbers, vectors, and matrices.	MATLAB basics MATLAB basics, including variables and matrixes, data I/O. Data processing in MATLAB. Basic statistics.	Computer hardware and software Basic constituents and functioning of computers. Bases, logic and logic gates. Computer operating systems, programs, and software. Compiled and interpreted languages.
02 / 4th April	Data visualization (in MATLAB)	Plotting data in MATLAB Data visualization – types of 1-D plots. 2-D plotting and interpolation. Re-gridding. Data binning and histograms.	Further visualization; Q&A.
03 / 11th April	Computer program fundamentals	Elements of MATLAB programming Loops and conditionals. Subroutines and functions. Further data processing techniques.	Further programming; Q&A Algorithms and numerical techniques. Search and sort algorithms. Programming best practice and debugging. Functions and subroutines.
04 / 18th April	Introduction to numerical models Time-stepping and integration techniques. Numerical stability and accuracy. Model code structure.	0-D ('box') modelling Basic geochemical box modelling and reservoir dynamics. Isotopes and fractionation.	Further numerical modelling; Q&A Worked and literature examples of (bio)geochemical box modelling and how these are coded.
05 / 25th April	1-D and reaction-transport models Structure and application of reaction-transport and other 1-D models to environmental problems.	1-D modelling Example models: (1) gas diffusion and consumption in soils; (2) firm enclosure and signal filtering of records in ice cores.	Discussion; work on MIDTERM

Figure 1: Course schedule: weeks 1 through 5.

	Monday am (1)	Monday am (2)	Friday pm
WEEK	Lecture A <i>08:10-09:00 -- GEOL 1444</i>	Computing lab <i>09:10-12:00 -- SPR 2101</i>	Lecture B <i>14:10-16:00 -- SPR 2101</i>
06 / 2nd May	2-D global environmental models #1 Fundamental climate system processes and their representation in models.	DIY climate model #1 Surface energy budget and greenhouse gases. Heat capacity. Atmospheric transport.	Visualizing 2-D (and 3-D) models
07 / 9th May	2-D global environmental models #2 Ice dynamics and feedbacks.	DIY climate model #2 Controls on ice melt. Controls on ice flow. Feedbacks with climate.	Evaluating numerical models Evaluation of numerical models. Model-data assessment. Numerical models in the literature, the work of the IPCC, and model 'inter-comparisons'.
08 / 16th May	Empirical and biological models Derivation and application of empirical relationships. Geochemical empirical models. Biological empirical models. Modelling ocean biogeochemical cycles.	Marine biogeochemical modelling Matrix maths. Calculation of ocean circulation by MATLAB matrix maths. Creating a basic biogeochemical cycling model.	Ecological modelling
09 / 23rd May	Complex models Resolution and numerics. Parallelization.	Global carbon cycling modelling Creating a basic global carbon cycle model.	Model dynamics Perturbing and analysing models.
10 / 30th May	The Internet How the internet 'works'. Computer networks. TCP/IP and network communication.	Basic html scripting Creating a basic webpage.	Discussion; work on FINALS

Figure 2: Course schedule: weeks 6 through 10.

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 60% of the total assessment of the course.

0.1.4 Office Hours

There are no specific Office Hours, but rather an open invitation to drop by¹ (excluding Thursdays) and/or email² 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

0.1.5 Course text

There is no one (or even two between them) complete course texts that covers both basic computer programming and numerical modelling at a suitable level, and certainly not in the context of MATLAB. However, the recommended course textbook; *Matlab (Third Edition): A Practical Introduction to Programming and Problem Solving*, by Stormy Attaway. Butterworth-Heinemann (2013). ISBN: 978-0-12-405876-7, represents a good basis for the MATLAB part of the course. For additional reading, potential texts include:

- *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.

Ultimately, the aim of the course (in future years) is to have a dedicated (free) text book in downloadable PDF format, of which the present document is the nucleus ...