Introduction to Earth system modelling

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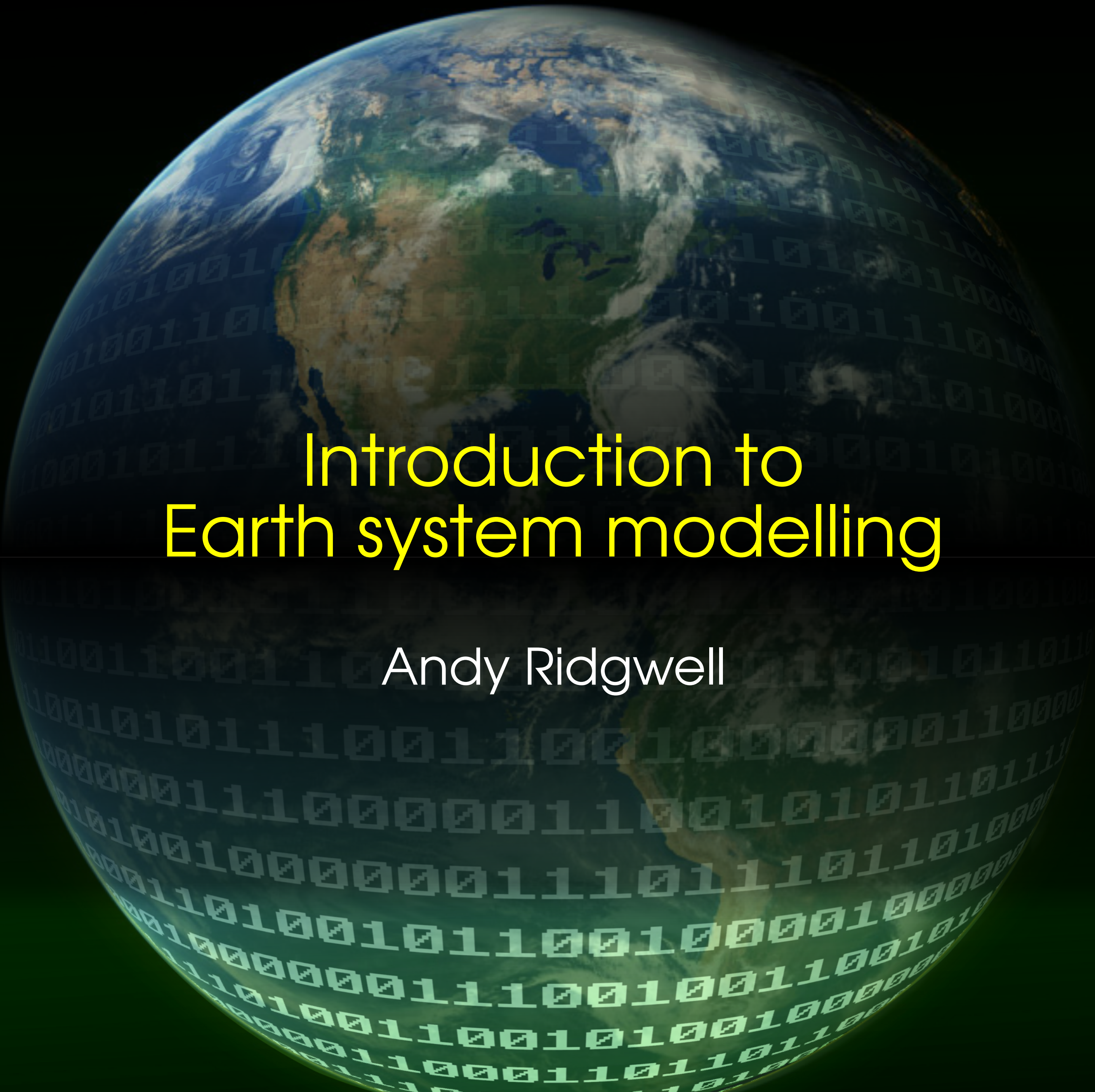

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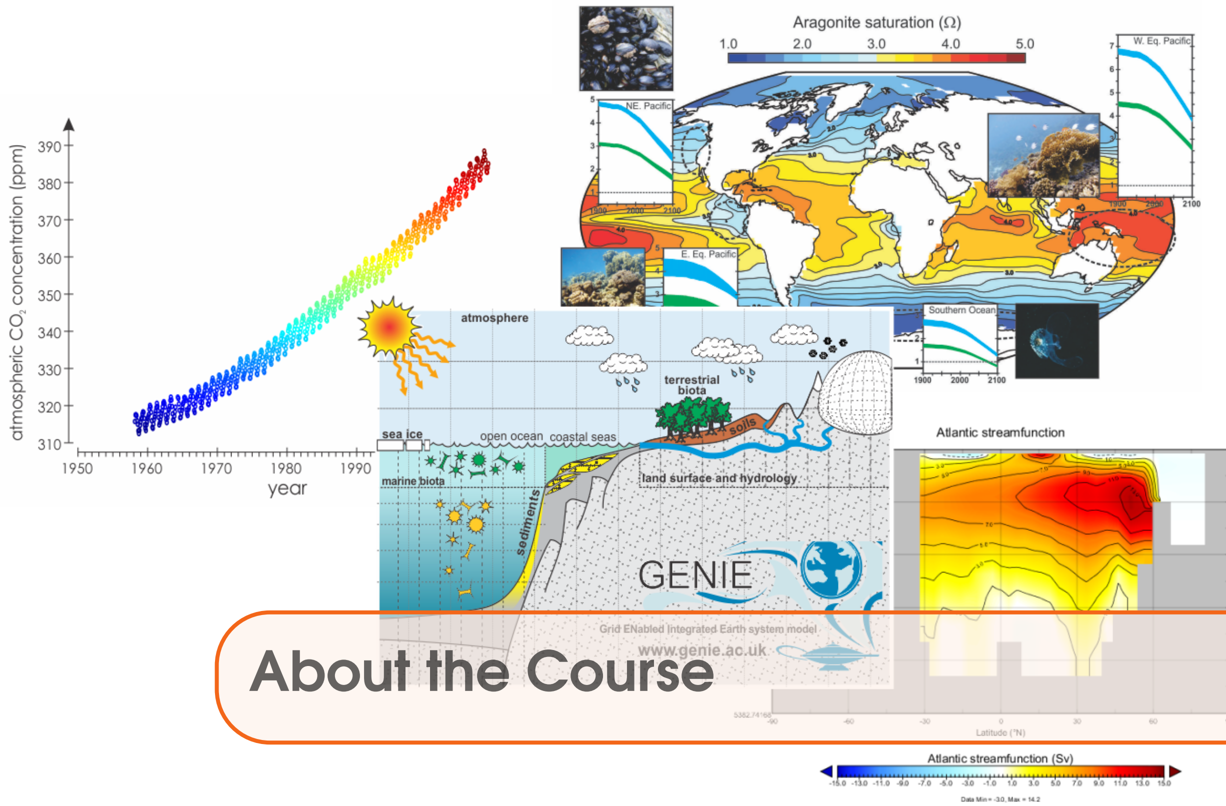

About the Course

This course will provide an introduction to, and practical hands-on learning in, Earth system modelling and dynamics. It will provide a chance to explore the dynamics of the Earth's climate system as well as of global carbon cycling (and other biogeochemical cycles) and include topical issues of past (geological) global change as well as a wide range of potential future global environmental impacts of fossil fuel CO_2 emissions and concepts in mitigation and geoengineering. But equally, the course will exemplify how numerical models can be utilized to address scientific questions, test hypotheses, and quantify the past and future relationship between global carbon cycling and climate and associated feedbacks. The course will facilitate the development of a variety of new computer skills and experience with data analysis and visualization techniques. The cumulating objectives of the course are to develop a deeper understanding of the role and nature of feedbacks in the Earth system and provide context to the impacts of current human activities and also and importantly, foster a critical appreciation of the nature and limitations of climate and Earth system modelling in understanding and predicting global change.

Upon completion of the course, you will be expected to have gained through hands-on practical exploration, factual knowledge and a mechanistic understanding of:

- The role and nature of feedbacks in the climate system and how climate is 'regulated', including the relationship and associated feedbacks between climate and global carbon cycling. (Learning Outcome 1)
- The primary controls on global ocean circulation patterns and stability. (1)
- The primary global climatic, biogeochemical, and ecological consequences of continuing fossil fuel CO_2 emissions, plus the costs and benefits of addressing future global change via geoengineering. (Learning Outcome 6).
- The primary controls on biological productivity and carbon storage in the ocean and on land. (1)
- The long-term (geological) regulation of global climate and atmospheric CO_2. (1)
- The use of numerical models in addressing scientific questions and testing hypotheses, as

well as the limitations of numerical model representations of climate dynamics and global carbon cycling. (Learning Outcomes 2 and 4)

The course will provide transferable skills in:

- Written communication and presentation. (Learning Outcome 3)
- Problem solving and quantitative analysis. (Learning Outcomes 4 and 5)
- Working in a unix-based computer environment, basic data analysis and computer programming in MATLAB plus techniques of data visualization, including both time-series and netCDF format spatial data. (Learning Outcomes 2 and 4)

Course details

Format

The weekly format of the Class is: 1 × 3-hour computer practical session, plus 1 × 3-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 configuring, running, and analysing the **cGENIE** Earth system model and using this to explore a series of basic assessments as well as topical issues in global carbon cycle and climate dynamics. The purpose of the 3-hour lecture/discussion session ending the week is to critically assess a published model and/or model-based scientific finding, using the **cGENIE** Earth system model as a tool to help further explore the assumptions made.

Each week, the Lab will take place on Tuesdays from 9:10am to 12:00pm in Watkins 2101, and the Lecture/Discussion on Fridays, 9:10am to 12:00pm (also in Watkins 2101). There will also be a brief introduction to the course on Friday 29th September at 9:10 am in Watkins 2101.

Timetable

The timetabling and overall course structure of GEO290 are given in Table 1.

Table 1: Schedule of GEO290

Week #	**Tuesday LAB**	**Friday Discussion/LAB**
01 (10/02)	GENIE modelling basics.	snowball Earth!
02 (10/09)	Exploring the nature and dynamics of ocean circulation.	The climatology of past worlds.
03 (10/16)	MATLAB and model data visualization & analysis.	(CONTINUED)
04 (10/23)	CO_2 emissions and climate change.	Ocean acidification and carbon geoengineering.
05 (10/30)	*Group work on snowball Earth project.*	**Group Presentation**
06 (11/06)	The ocean's biological pump (and further geoenginering).	UCR HOLIDAY
07 (11/13)	Marine ecology.	(CONTINUED)
08 (11/20)	Terrestrial carbon cycle dynamics and climate feedback.	UCR HOLIDAY
09 (11/27)	The geological carbon cycle.	(CONTINUED)
10 (12/02)	*Individual work on Finals project.*	*(CONTINUED)*

Assessment

The course will be assessed as follows:

- Midterm / group presentations – 40%
- Finals / individual paper – 60%

The Mid-term assessment will be in the form of a group presentation, presenting the results of a short model-based investigation carried out in the week (or weeks) beforehand. The topic will concern 'snowball Earth'. The presentation is expected to be 30 minutes long and all group members must participate. There will be questions, both from the instructor and audience (remainder of the class) following.

The Finals assessment will be based upon an Earth system model based research investigation – guidance will be provided as to potentially suitable topics along with detailed background and suggestions for investigative directions and experiment design. The assessment will be in the form of a written report in a Nature Article format. Marking and feedback will be based on the quality of article, appropriateness of the modelling methodology ad its description, depth and innovation of the model (and model-data) analysis, adequate appreciation of the literature, and ability to convey information and concepts to a relatively general audience.

Office Hours

There are no specific Office Hours, but rather an open invitation to drop by[1] (excluding Thursdays) and/or email[2] questions. Wednesdays (almost any time) would be your best chance of finding me (and not busy).

Course text

This is it!

Course technical details

Logistics

The labs are based around using and analysing the '**cGENIE**' Earth system model[3]. You will be working in groups of 2 (or 3) and will be remote accessing a computing cluster (where the model will actually run)). You will hence need some means of accessing the remote computer. Unless you are some sort of wizard, I suggest a lab desktop, or your own laptop, connected to the internet.

In terms of group working dynamics – if everyone each brings a laptop, then in a group of 2 it becomes easier to be e.g. managing configuring and running the model on one laptop, and analysing results or displaying instructions/documentation on another other.

Required software

If you chose to use a lab desktop, which will be a Windoz 10 based machine, all the software you need will be pre-installed.

If you plan on using your own laptop to remote access the model and visualize results, you will need some specific software. The exact software will depend on your operating system, but everyone will need:

1. A terminal ('shell') window. This is no problem for linux and Mac users (you already have one built in). For Windows, either download a simple (and old) SSH client (ssh-client) from my website[4] or you can get hold of e.g. PuTTY (http://www.putty.org/).

[1] My office is in the Geology building, room 464 (basement floor).
[2] andy@seao2.org
[3] http://www.seao2.info/mycgenie.html
[4] http://www.seao2.info//cgenie/software/ssh-client.exe

2. A sftp (secure file transfer) client for convenience (i.e. dragging and dropping files between local and remote computers, and opening files directly on the remote computer cluster). If you have installed ssh-client (Windows, above) then a sftp client is already included as part of this software. If using PuTTY (Windows) you might try downloading WinSCP (http://winscp.net/eng/index.php). For the Mac – I am told that Cyberduck is OK (there are bound to be many other alternatives). For linux, maybe FileZilla.
3. A viewer for netCDF format spatial data. A Java viewer called Panoply is provided by NCAR for all platforms – http://www.giss.nasa.gov/tools/panoply/ (Note that you will need Java installed!)
4. A simple text editor, except not the rubbish default Windows one – you need one that can display unix ASCII text without screwing it up. Options for Windows users are: notepad++ (https://notepad-plus-plus.org/) SciTE (http://prdownloads.sourceforge.net/scintilla/Sc372.exe) (linux and Mac users need no special/different editor compared with your standard editor – everything will display just fine).

Running cGENIE.muffin on a laptop

It is also possible to install and run the '**cGENIE**' Earth system model on a linux box (e.g. Ubuntu) or a Mac. Sets of instructions ('Quick-Start Guides') are available on my website[5] (in the 'got muffin?' box on the left).

Note that it is not possible at this time to run **cGENIE** ('muffin' version) under Windows (at least, not without near infinite pain).

Also note that if you have trouble installing and running **cGENIE** on your own linux box or Mac, there may not be time to sort out the problem (and in any case I have no clue at all about Macs). If so, you'll have to access and run the model remotely. (There are also advantages to running on the remote cluster as you will see in due course.)

[5] http://www.seao2.info/mycgenie.html

Assignment – Mid-term presentation

Assignment – Finals project

Instructions

Carry out an investigation using the **cGENIE.muffin** model ... and write it up! Thats it!

(OK, some more info.)

The investigation can be based on facets of the Earth system (as represented in **cGENIE.muffin**) that have been covered in the course, or it could go beyond that. The investigation could also build on specific experiments and investigations from the course, or be a completely new and different research topic.

However, the investigation should not simply be a repeat of course material. You should also avoid doing something that is only incrementally different from a course experiment/investigation.

You should aim to formulate a hypothesis, or series of hypotheses, that you test using the model. Ideally, the questions addressed will have an interesting purpose and point, relevant to e.g. to past or future climate change or some fundamental process in the modern ocean. Indeed, in the introduction and background of the paper, you will be needing to set the scene and describe the relationship of your study to the relevant literature.[6]

Format

For the format – follow the 'manuscript formatting guide' guide for Nature. Use the instructions for writing a Nature 'Article', e.g.:

- <3000 words for the main text
- no more than 5-6 Figures (and Tables)
- a brief model and methodology description should be included in a 'Methods' section (see Nature guidelines)

If you would like to show additional model plots and/or description that is not central to the conclusions of your paper – you can include a separate section of 'Supplementary Information'.

You do not have to number the references: writing them out as e.g. '*Watson et al.* [2000]' rather than reference '*(3)*' or '[3]' in the main text is fine. Nor are you expected to produce a layout that looks like a published paper (although that is fine if you would like to).

Hand-in date is: midnight on Friday 8th December 2017. Hand-in is electronically by email – ideally in PDF format, but Word format files are acceptable. Ideally this should be as a single file, but it is OK to split into a maximum of 3 files: main text, figures, and Supplementary Information / Extended Methods. Please, do not send all the figures as individual files ...

Remember: Running the model experiments and the write-up must be done individually.

This paper constitutes 60% of the course marks.

[6] A hypothesis and associated study based on the question: 'Does the ocean cool down if the Sun is switched off?' ... is just not going to nail it.