Introduction to
Earth system modelling

Andy Ridgwell
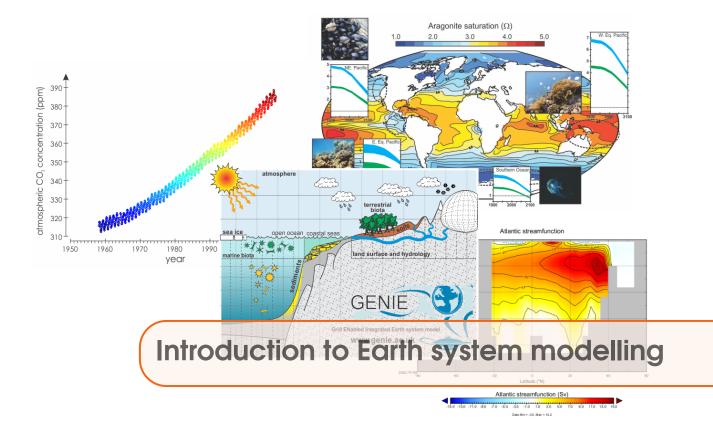
Introduction to Earth system modelling

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, some sort of understanding about:

- 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.
- The nature and some of the controls on global ocean circulation patterns and stability.
- Some of 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.
- The primary controls on biological productivity and carbon storage in the ocean.
- 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)

Workshop logistics

The labs are based around using and analysing the **muffin** cGENIE Earth system model[1]. You will be working in groups of 3 (or 2) 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.

The workshop will be held in room 1.3n – the 'Haggett Lab', in the School of Geographical Sciences. Coffee/tea and lunch will be served in the Geography common room.

Required software for remote accessing the muffin model

If you chose to use a lab desktop, which will be a Windoz 7 or 10 based machine, all the software you need will be pre-installed ... perhaps ... If not – specific instructions/guidance will be given at the beginning of the workshop.

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[2] or you can get hold of e.g. PuTTY (http://www.putty.org/).

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, you can connect to the server through the Terminal, but some sftp software for viewing/navigating server file structure include: FileZilla (use this one), Cyberduck, TextWrangler. Also 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 muffin directly 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. In the muffin user manual[3] – see Section 17.4 for instructions for installing under Ubuntu 18.04, and Section 17.6 for macOS.

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[1]http://www.seao2.info/mycgenie.html
[2]http://www.seao2.info//cgenie/software/ssh-client.exe
[3]http://www.seao2.info/cgenie/docs/muffin.pdf

Note that it is not possible at this time to directly run **cGENIE** ('muffin' version) under Windows (at least, not without near infinite pain). But you can use **cygwin**, apparently ...

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.)

Instructions specific to the workshop

In addition the specific software installed on the computer lab PCs, sever of the directions for this workshop will deviate from the generic instructions contained in the muffin manual. Pay attention, and note and follow the revised instructions (as detailed in the workshop Schedule table).

Reading list

For all/most references, accepted author versions, full published PDFs, or links to publisher website, can be found on: http://www.seao2.info/pubs.html

Descriptions of the basic climate model component

- Edwards and Marsh [2005] (Climate Dynamics 24, 415-433)
  (description and calibration of the climate model component of (c)GENIE)
- Hargreaves et al. [2004] (Climate Dynamics 23, 745-760)
  (description of data assimilation methodology and calibrated climatology of the climate model)

Descriptions of the basic ocean carbon and nutrient cycle component

- Ridgwell et al. [2007a] (Biogeosciences 4, 87-104)
  (description of basic ocean carbon cycle and its calibration against observations)
- Tagliabue, A., O. Aumont, R. DeAth, J.P. Dunne, S. Dutkiewicz, E. Galbraith, K. Misumi, J.K. Moore, A. Ridgwell, E. Sherman, C. Stock, M. Vichi, C. Völker, and A. Yool, How well do global ocean biogeochemistry models simulate dissolved iron distributions?, GBC DOI: 10.1002/2015GB005289 (2016).
  (multi-model evaluation of the Fe cycle component)

For the optional ecosystem modelling activity

- Ward, B.A., J.D. Wilson, R. Death, F.M. Monteiro, A. Yool, and A. Ridgwell, EcoGEnIE 0.1: Plankton Ecology in the cGENIE Earth system model, Geosci. Model Dev. Dis. (in revision)
  – https://www.geosci-model-dev-discuss.net/gmd-2017-258/

Schedule

Monday 3rd September

time	Activity
10.00-10.30	**Presentation – Course and methodology overview**
coffee break	
11.00-12.30	**Session 0 – Getting started**
	Accessing the computing cluster; installing and compiling cGENIE; directory structure ('where everything is'). Command-line operation; how to submit jobs to a cluster queue. Use of 'restart' experiments and modelling methodologies. Visualization of model output: time-series and time-slice (2D and 3D) output.
	To-do:
	(i) Section 1.1 (recap of general workshop software information and instructions).
	(ii) Sections 1.2.1 and 1.2.2, but: after cloning the muffin code (and still in the `cgenie.muffin` directory), type:
	`git checkout uob2018`
	to switch to ('checkout') a workshop specific version of the model code.
	(iii) Skip Section 1.2.3 (as is it not needed having checked out the workshop configured code).
	(iv) Section 1.2.4.
	(v) Sections 1.3 through 1.7 (i.e. to the end of Chapter 1).
	(vi) Also – for more details on plotting with **Panoply**, see Section 13.2. If you like **MATLAB** – see Section 13.3.
	Further information about model data saving (how to save more/less, how frequently, where is it, what to look out for, etc) can be found in Chapter 12.
lunch	
13.30-15.00	**Session 1 – A 'real'(!) experiment**
	Setting up experiments: configuration files and setting parameter values. Exploring Earth system dynamics: 'Snowball Earth' and climate feedback.
	To-do:
	(i) Chapter 2 – Section 2.1.
coffee break	
15.30-17.00	**Session 1 – A 'real'(!) experiment – CONTINUED**
	(ii) Section 2.2.2
	(iii) Section 2.2.3 (optional, conceptual continental configuration exploration)
	(iv) Section 2.2.4 ('real' 635 Ma age continents!)
	(v) Move on to: **Session 2 – 'Poking the climate beast'** (see Tuesday instructions)

Tuesday 4th September

time	Activity
9.00-10.30	**Session 2 – 'Poking the climate beast'** Applying perturbations and tracing ocean circulation. Exploring the stability of the Atlantic meridional overturning circulation ('AMOC'). **(i)** First – to add some new configuration files to your installation of **muffin** – from the `cgenie.muffin` directory, type: `git pull` **(ii)** Section 3.1 (*Tracing* ocean circulation). **(iii)** Section 3.3.4 (*Ventilation age tracers*). (Skip the perturbations of ocean circulation, that come later (you can always return to assessing ocean water mass ventilation age changes later.))

<div align="center">coffee break</div>

time	Activity
11.00-12.30	**Session 2 – 'Poking the climate beast' – CONTINUED** **(iv)** Section 3.2 (*Poking the climate beast*). **(v)** Section 3.3.3 (*Response to transient warming*).

<div align="center">lunch</div>

time	Activity
13.30-15.00	**Session 3 – Poking the carbon cycle** CO2 emissions and the spatial patterns of ocean acidification.

<div align="center">coffee break</div>

time	Activity
15.30-17.00	**Session 4 – Engineering the carbon cycle** Sensitivity of atmospheric pCO2 and ocean acidification to changes in the ocean's biological pump and 'weathering'. Ocean carbon cycle geoengineering.

Wednesday 5th September

time	Activity
9.00-10.30	**Selected activity(s)**
coffee break	
11.00-12.30	**Selected activity(s)**
lunch	
13.30-15.00	**Selected activity(s)**
coffee break and depart	

Optional Activities

The optional activity choices[4] on the Wednesday will be:

1. **Ecosystem modelling.**
   (i) First – to add some new configuration files to your installation of **muffin** – from the `cgenie.muffin` directory, type:
   `git pull`
   (ii) Follow: Chapter 9.
   NOTE: <u>not</u> Section 9.5.

2. **Engineering the carbon cycle.**
   Sensitivity of atmospheric pCO2 and ocean acidification to changes in the ocean's biological pump and 'weathering'. Ocean carbon cycle geoengineering.
   See: Chapter 8.

3. **Climates and ocean circulation in past and fake Worlds.**
   See: Chapter 5.
   [INSTRUCTIONS IN PROGRESS ...]

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[4]It is possible to pick at both options somewhat successfully (e.g. one am, one pm).