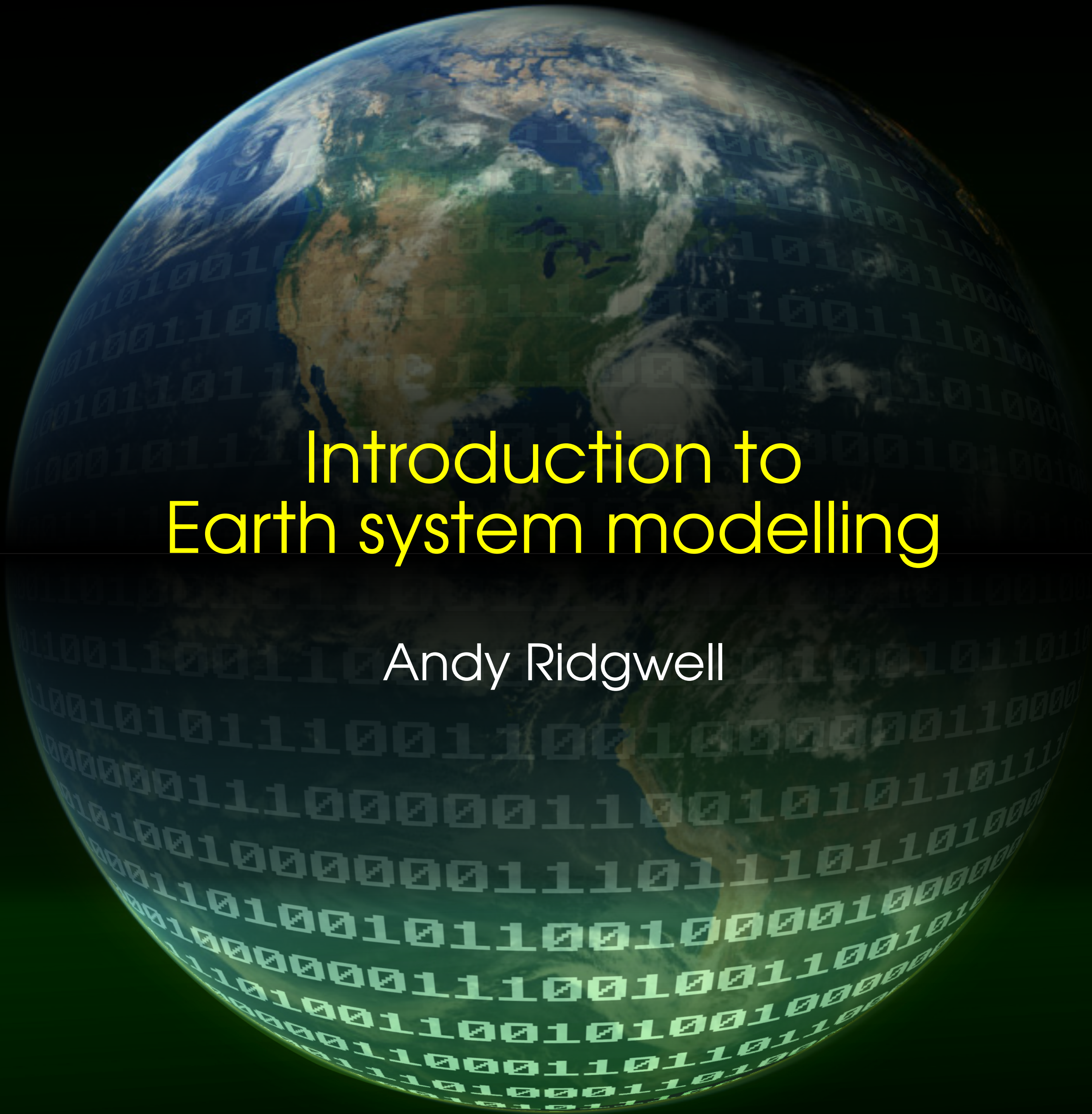

Introduction to Earth system modelling

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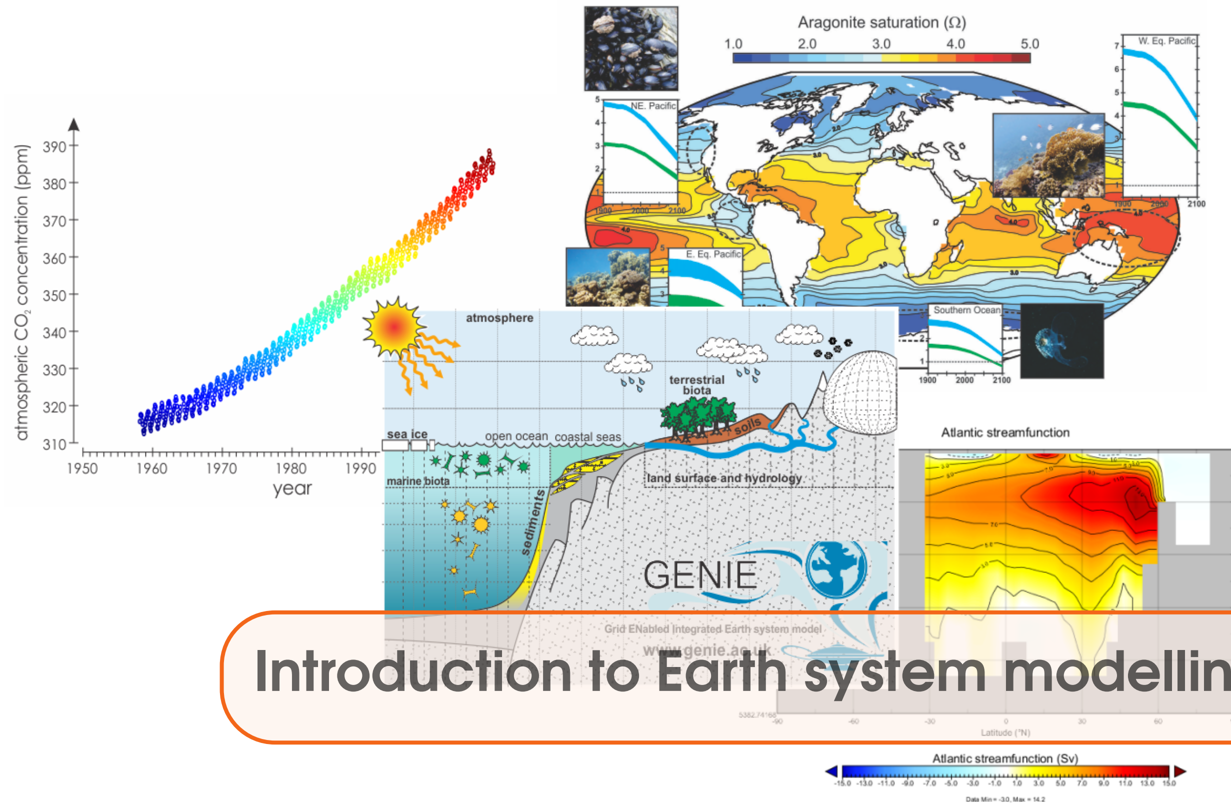

Introduction to Earth system modelling

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. And have fun. etc etc.

No-one is expected to ever compile **muffin** (aka the 'cGENIE' Earth system model) again. It is an example of an Earth system model ... and a convenience to 'play with' and explore some stuff. This workshop is not designed as a **muffin** training course to spit out identikit collaborators. Of course, if after the workshop, you wish to continue using and running experiments and testing hypotheses with **muffin**, please do ...

Workshop logistics

There are actually no ’logistics’ – we will all be working remotely ... because the World sucks.

Required software for remote accessing the muffin model

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[1] 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 **muffin** on a linux box (e.g. Ubuntu) or a Mac. In the muffin user manual[2] – see Section 20.5 for instructions for installing under Ubuntu 18.04, and Section 20.7 for macOS.

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** – see Section 20.8.

Also note that if you have trouble installing and running **muffin** 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.)

Accessing additional tutorials and means of plotting results

MATLAB ... if you are familiar with **MATLAB**, there is one fun additional exercise involves **MATLAB**. Additional means of plotting and visualizing are provided that also require this software.

[1] http://www.seao2.info//cgenie/software/ssh-client.exe
[2] https://github.com/derpycode/muffindoc/blob/master/muffin.pdf

Documentation / instructions

All the instructions, exercise/tutorial descriptions, etc., can be found in the muffin user manual[3]. (This can also be edited and re-compiled from its latex source.)

[3]https://github.com/derpycode/muffindoc/blob/master/muffin.pdf

Reading list

For all/most references, accepted author versions, full published PDFs, or links to publisher web site, 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)
- Marsh et al. [2011] (doi:10.5194/gmd-4-957-2011)
  (updated description and calibration of the climate model component of (c)GENIE)

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 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. – doi.org/10.5194/gmd-11-4241-2018
  (description of the ecosystem model component)

Schedule

Wednesday 1st July

time (EST)	**Activity**
10.00-10.30	**Presentation — Course and methodology overview**
10.30-12.00	**Session 0 — Getting started** Accessing the computing cluster; installing and compiling **muffin**; 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)** Section 1.2.1 (logging in) **(ii)** Section 1.2.2 – follow the instructions for 'cloning' the model code **(ii)** Section 1.2.3 – follow the instructions for the 'domino' cluster. (This is somewhat going to be a test of your patience and sanity but it is a genuinely healthy computer/model experience.) **(iv)** Section 1.2.4 (testing the installed model code). **(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 Chapter 15. If you like **MATLAB** – see Chapter 16. 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 14.

break

13.00-15.00	**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.

break

15.30-17.00	**Session 2 — 'Poking the climate beast'** Applying perturbations and tracing ocean circulation. Exploring the stability of the Atlantic meridional overturning circulation ('AMOC'). **To-do:** **(i)** Section 3.1 (*tracing* ocean circulation). **(ii)** Section 3.2 (AMOC perturbation experiments).

Thursday 2nd July

time (EST)	**Activity**
10.00-12.00	**Session 3 — ‘Poking the carbon cycle’** CO_2 emissions and the spatial patterns of ocean acidification. **To-do:** **(i)** Section 6.1 - Exploring the consequences of fossil fuel CO_2 emissions. Make sure that before spending too long on Section 6.1.1, you read through 6.1.2 and get the historical transient experiment running (needed for a subsequent set of experiments). **(ii)** Section 6.1.2 - The historical transient.
	break
13.00-14.00	**Session 3 -– Poking the carbon cycle’ – CONTINUED** **To-do:** **(i)** Section 6.1.2 - The historical transient. **(ii)** Section 6.1.3 - Future emissions scenarios.
	break
14.30-17.00	**Session 4 — Ocean Biogeochemical Cycles OR an ’Optional Activity’** Ocean nutrient, carbon, and oxygen cycling. **To-do:** **(i)** Section 7.2 (and read 7.1). Also, read the references indicated.

Optional Activities

1. **Past worlds – Chapter 5.**
2. **Alternative worlds – Chapter 6.**
   This requires that you have **MATLAB** installed on your laptop.
3. **Ecosystem modelling – Chapter 8.**
   (This can be combined with Chapter 6 to explore alternative ecosystems in alternative worlds, or with Chapter 5 to explore alternative ecosystems in past worlds.)
4. **Ocean proxies – Chapter 12.**
   This will be developed further during the morning with additional experiments and fun activities available after lunch. (So e.g. one could start off on this, switch to another activity later in teh morning, then return to it after lunch.)