GEO XXX: A Practical Introduction to Earth System Modelling and Dynamics

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Graduate course, lecture/lab. Geo xxx. Pierce xxxx.

Units:

4 unit course

Hours per week:

Lecture: 3
Lab: 3

Description:

This course will provide an introduction to and practical hands-on learning in Earth system modelling. It will provide a chance to explore the dynamics of the Earth's climate system as well as of global carbon cycling and include topical issues of past (geological) global change as well as the global environmental impacts of fossil fuel CO_2 emissions and concepts in geoengineering. The course will foster a critical appreciation of the nature and limitations of climate and Earth system models in trying to understand and project global change. 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 provide learning of new computer skills and gaining of experience with data analysis and visualization software and 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.

Prerequisites:

TBA

Course syllabus:

The course is structured as two 1.5 hour lectures per week plus one 3.0 hour lab class per week. The first lecture each week provides an introduction to the basic science underlying the computer modelling lab material of that week. The second lecture covers how the environmental processes introduced that week can be (and have been in the literature) implemented in models and includes an opportunity for discussion about creating and applying numerical models to global environmental change questions and issues arising.

Week 1

Lecture 1: *Introduction to the course.*
Introduction to global environmental modelling.

Lab: Key linux and MATLAB skills.
Techniques for visualizing time-series and spatial netCDF-format data.

Lecture 2: *Introduction to 'GENIE' Earth system model.*
Computer modelling philosophy discussion.

Week 2

Lecture 1: *Extreme perturbations of climate and carbon cycling associated with 'snowball Earth'.*

Lab: GENIE modelling basics: Accessing the computing cluster; installing and compiling GENIE; directory structure ('where everything is'). Command-line operation; how to submit jobs to a cluster queue. Use of 'restart' experiments and modelling methodologies. Setting up experiments: configuration files and setting parameter values.
Experiments and research into climate hysteresis and 'tipping points' and specifically: 'snowball Earth'. Lessons in model output analysis and visualization.

Lecture 2: *The different ways of representing climate components in numerical models: advantages and disadvantages.*
Discussion.

Week 3

Lecture 1: *Fundamental controls on and patterns of ocean circulation.*

Lab: Applying perturbations to the model and tracing ocean circulation.
Exploring the stability of the Atlantic meridional overturning circulation ('AMOC'). More on climate hysteresis and 'tipping points'.
Further lessons in output analysis and visualization.

Lecture 2: *Modelling the ocean circulation; from box models to regional OGCMs.*
Discussion.

Week 4

Lecture 1: *(Fossil fuel) CO_2 release and ocean acidification.*

Lab: Magnitude and spatial patterns of the climate and ocean acidification impacts of CO_2 emissions. Historical ocean CO_2 uptake and dynamics.
Future emissions scenarios and mitigation.

Lecture 2: *Biotic sensitivities and impacts of ocean acidification.*
Discussion: just another climate 'scare'?

Week 5

Lecture 1: *The basic functioning of the 'biological pump' in the ocean.*

Lab: Controls and sensitivities of the ocean's biological pump. Controls on ocean

biogeochemical cycles and tracer distributions.
Assessing (Earth system) models against data (modern observations).

Lecture 2: *The biological pump through time and importance of key biological innovations.*
Discussion: representing incompletely understood yet complex systems.

Week 6

Lecture 1: *Climate change mitigation and geoengineerng.*

Lab: Sensitivity of atmospheric CO_2 and ocean acidification to changes in the ocean's biological pump and 'weathering'. Ocean carbon cycle geoengineering.

Lecture 2: *Debate on mitigation vs. geoengineering (vs. adaptation).*

Week 7

Lecture 1: *Role of the land surface and terrestrial biosphere.*

Lab: Atmosphere-land surface interactions and terrestrial biosphere CO_2 feedback.

Lecture 2: *The terrestrial biosphere through time and importance of key innovations.*
Discussion.

Week 8

Lecture 1: *Ocean-sediment interactions and long-term controls on atmospheric CO_2 I – the geological inorganic carbon cycle.*

Lab: Global calcium carbonate cycling dynamics and role of deep-sea sediments and the long 'tail' of fossil fuel CO_2 release.

Lecture 2: *Evidence from the geological record.*
Discussion.

Week 9

Lecture: *Ocean-sediment interactions and long-term controls on atmospheric CO_2 II – the geological organic carbon cycle.*

Lab: Organic carbon burial. Ocean redox.

Lecture 2: *Evidence from the geological record.*
Discussion.

Week 10

Lecture 1: *Use of models in interpreting the geological record.*

Lab: Warm climates of the past – controls on and spatial patterns of surface temperature and ocean circulation during the Cretaceous and Paleocene-Eocene.
Mechanisms of glacial atmospheric CO_2.

Lecture 2: *Introduction to and Q&A on the assessment.*

iLearn:

Lab instructions, model resources, etc. will be made available week-by-week on the internet: http://www.seao2.info/mycgenie.html

Lecture handouts (PDF format) will be made available prior to the start of the lecture in a compact printable and annotatable format.

Course goals:

Upon completion of the course, students 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. (*Learning Outcome 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. (*Learning Outcome 1*)
- The long-term (geological) regulation of global climate and atmospheric CO_2. (*Learning Outcome 1*)

as well as:

- The use of numerical models in addressing scientific questions and test 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*)

Assessment:

Assessment of the course 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 two parts:
Firstly, a short conference-style oral presentation of the investigation results. This will count for 20%.
Secondly, a written report in a Nature Article format. This will count for 80%.
Marking and feedback will be based on the quality of presentation (written and graphical), appropriateness of the modelling methodology, depth and innovation of the model (and model-data) analysis, and adequate appreciation of the literature.

Course textbook:

None.

Recommended reading:

Lists of recommended and relevant publications will be provided on a week-by-week basis.