GEOL1950M Syllabus
Geoengineering
Or, The Unnatural World

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Or, The Unnatural World
Examines the processes, dynamics, and consequences of geoengineering, or intentional climate intervention, approaches to controlling climate change. Through assignments students will create a series of referenced, researched, public wikipedia pages summarizing the state of the art understanding (i.e., a geoengineering hackathon). Intended for undergraduate and graduate students with interests in oceans, climate, paleoclimate, engineering, and climate change policy. Pre-requisite: GEOL0240 or ENVS0490 or GEOL1350 recommended; permission of instructor required. Enrollment limited to 30.

Key Words: Climate, Climate forcing, Climate sensitivity, Ocean Data, Atmosphere Data, Research projects

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1. Contacts

The lead professors for this class are:

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The overall class info can be found at `http://fox-kemper.com/teaching`, `http://fox-kemper.com/geoengineering`. Portions of the website are password-protected to ensure that fair use and copyrights are correctly obeyed as I share images from books, etc. You can access these by using:

```
username:  io
password:  ocean
```

2. Getting Help!

We are usually available by email. You can make an appointment if needed. Just check Baylor's calendar at `http://fox-kemper.com/contact` and suggest a time that works for you. Professors in the class are: `mailto:baylor@brown.edu` (Oceans, Modelling), `mailto:meredith_hastings@brown.edu` (Atmospheric Sciences), `mailto:greg_hirth@brown.edu` (Carbon Capture, Geochemistry), `mailto:james_russell@brown.edu` (Paleoclimate).

3. Meetings and Places

We will meet Tuesdays and Thursdays from 2:30 to 3:50PM in MacMillan 101. Office hours are Tuesdays 4-5 in MM101 or by appointment.

The faculty will meet in GC150 at 9-10 Friday mornings to plan for each upcoming week. If you have suggestions for activities, concerns, etc., please inform us by 8AM Friday.

4. Guest Lecturers

These will be scheduled based on lecturer availability.

We also plan to host some outside speakers. These speakers would present and we would discuss for one class period, with a matched reading assignment selected in consultation with the guest. Presently scheduled are Timmons Roberts (9/21) and Dov Sax (11/14).

5. Goals

In this class you will:

1. Learn about many of the physical processes that control the Earth's climate.
2. Learn how humans do and may affect these processes inadvertently or deliberately.
3. Learn some direct and indirect effects of human perturbations to the climate system.
4. Get practice writing and thinking scientifically by summarizing peer-reviewed research for a broad audience.
5. Gain a broader perspective and practice by reviewing your peers' efforts.
6. Benefit from reviews of your writing by your peers.

Over the course of the semester, each student will complete two large projects (collaboration on a wikipedia page), and an assortment of smaller projects (peer reviewing, summaries, etc.).

The topics we will cover are:

1. Module 1: Climate Change (4 Weeks)
   Climate Change: The Physical Science Basis (2 Weeks Discussions/Lecture)
   Climate Change: Impacts, Adaptation, and Vulnerability (1 Week Discussions/Lecture)
   Climate Change: Mitigation of Climate Change (1 Week Discussions/Lecture)
2. Module 2: Modifying Outgoing Radiation (3 Weeks)
   Local carbon capture and storage
   Remote carbon capture and storage
   Ecosystem manipulation
3. Module 3: Modifying Incoming Radiation (3 Weeks)
   Stratospheric aerosols
   Nuclear winter
   Cloud brightening/alteration
   Surface albedo changes
4. Module 4: Other Approaches (3 Weeks)
   Climate control
   Urban relocation
   Greening a city
   Terraforming and space colonization

6. Reading

We will read David Biello's *The Unnatural World* (Amazon Link, (Biello 2016)), which presents a more human perspective on issues and ethics of climate change and geoengineering, as well as peer-reviewed articles and technical reports. The readings by week (and links) are listed here, but the class-by-class calendar is here: `http://www.geo.brown.edu/research/Fox-Kemper/classes/GEOL1950M_17/notes/`.

(*a*)Module 1: Climate Change

Week 0, 9/7, 1) Syllabus.

Week 1, 9/12, 1) IPCC *Climate Change: The Physical Science Basis*, Policymaker Summary (Alexander et al. 2013). 2) Gertner (2017): Is it o.k. to tinker with the environment to fight climate change?

Week 1, 9/14, 1) IPCC Fifth Assessment. *Climate Change: The Physical Science Basis*, Stocker et al. (2013). 2) Pierrehumbert (2017): The Trouble with Geoengineers "Hacking the Planet".

Week 2, 9/19, 1) IPCC *Climate Change: The Physical Science Basis*, Stocker et al. (2013). 2) Clark et al. (2016).

Week 2, 9/21, 1) IPCC *Climate Change: Impacts, Adaptation, and Vulnerability*, Field et al. (2014). Timmons Roberts guest lecture (9/21).

Week 3, 9/26, 1) Biello, *The Unnatural World*, Chapter 2: Written in Stone (Geological Record). 2) IPCC *Climate Change: Impacts, Adaptation, and Vulnerability*, Field et al. (2014).

Week 3, 9/28, 1) Biello, *The Unnatural World*, Chapter 2: Written in Stone (Geological Record). 2) Ruddiman (2003).

Week 4, 10/3, 1) IPCC Fifth Assessment. *Climate Change: Mitigation of Climate Change*, Edenhofer et al. (2014). 2) Pacala and Socolow (2004).

Week 4, 10/5, 1) IPCC Fifth Assessment. *Climate Change: Mitigation of Climate Change*, Edenhofer et al. (2014). 2) Carbon Lab. 3) Energy Lab.

(*b*)Module 2: Modifying Outgoing Radiation

Week 5, 10/10, 1) Biello, *The Unnatural World*, Chapter 3: Ground Work (Surveying, Terrestrial Carbon). 2) McNutt et al. (2015a), Chap. 2.

Week 5, 10/12, 1) Biello, *The Unnatural World*, Chapter 3: Ground Work (Surveying, Terrestrial Carbon). 2) Zimov (2005).

Week 6, 10/17, 1) Biello, *The Unnatural World*, Chapter 7: The Long Thaw (Solid Earth Carbon Capture). 2) Kelemen and Matter (2008). 3) Sections 1.1 to 1.4 of McCulloch (2016).

Week 6, 10/19, 1) Biello, *The Unnatural World*, Chapter 7: The Long Thaw (Solid Earth Carbon Capture). 2) Ellsworth (2013). 3) Abstract, Introduction, Conclusion & Figures only of Huppert and Neufeld (2014), 4) Abstract, Introduction, Summary & Recommendation, & Figures only of Bachu (2015)

Week 7, 10/24, 1) Biello, *The Unnatural World*, Chapter 1: Iron Rules (Ocean Fertilization and Carbon). 2) Powell (2008b,e,d,a,c); Nevala and Madin (2008) (Module 2 writers, no summary for week 7).

Week 7, 10/26, 1) Examine CDR-MIP. 2) McNutt et al. (2015b), Chap. 2. David Battisti guest lecture.

Optional, Chapter 3 of McNutt et al. (2015a) is useful for module writing & review.

(*c*)Module 3: Modifying Incoming Radiation

Week 7, 10/26, Note that reading 2) McNutt et al. (2015b), Chap. 2., anticipates Module 3.

Week 8, 10/31**Module 2 Writing Project Due at Midnight.**

Week 8, 10/31, 1) Crutzen (2006). 2) Robock (2016). 3) Pidgeon et al. (2013). Brad Marston guest Lecture.

Week 8, 11/2, 1) Kravitz et al. (2013b). 2) Kravitz et al. (2013a). 3) Jones et al. (2013).
Week 9, 11/7, 1) Shepherd et al. (2012). 2) Neumann et al. (2015). 3) Berdahl et al. (2014).
Week 9, 11/7**Review of Module 2 Writing Project Due**
Week 9, 11/9, 1) Tilmes et al. (2013). 2) Curry et al. (2014). 3) Stevenson et al. (2016).
Week 10, 11/14, 1) Biello, *The Unnatural World*, Chapter 4: Big Death (Extinctions). 2) Ecology Lab. Dov Sax guest lecture (11/14).
Week 10, 11/16, 1) Biello, *The Unnatural World*, Chapter 5: The People's Epoch (Population Growth, China). 2) Demographics Lab.
Week 11, 11/211) Alterskjær et al. (2013). 2) Gabriel et al. (2017) **Module 3 Writing Project Due at Midnight.**

Optional, Chapter 3 of McNutt et al. (2015b) is useful for module writing & review.

(*d*)**Module 4: Other Approaches**
Week 12, 11/28, 1) Canadell et al. (2007). 2) Keith et al. (2017). 3) Biello, *The Unnatural World*, Chapter 6: City Folks (Cities, Circular Economies). 2
Week 12, 11/30**Module 3 Writing Project Reviews Due.**
Week 12, 11/30, 1) Pielke Sr. (2005). 2) Ruddiman (2013). 3) Ng et al. (2012). (Module 3 writers, no summary on week 12 due).
Week 13, 12/5, 1) Biello, *The Unnatural World*, Chapter 8: The Final Frontier (Technology, Space Colonization). 2) Frieler et al. (2016). 3) Lohmann and Gasparini (2017).
Week 13, 12/7, 1) Biello, *The Unnatural World*, Chapter 8: The Final Frontier (Technology, Space Colonization). 2) Beech (2009). Wrap-up of Final Projects. Biello, *The Unnatural World*, Chapter 8: The Final Frontier (Technology, Space Colonization).
Week 15, 12/18**Independent Writing Project Due by Noon.**

7. Assignments and (lack of) Exams

Once per week, each student will upload a short ($<$ 1 page) document on canvas containing: 1) Summary (100 words per paper or talk in that week), 2) Comparative Strengths (50 words total, covering all papers and talks), 3) Comparative Weaknesses (50 words total, covering all papers and talks), 4) Brainstorm (100 words total) (i.e., connections to other reading, discussion, hopes, dreams, fears, etc.). There will be 1 of these summaries each week, totaling $<$ 1 page of writing covering 1-4 items per week. These summaries will be re-used to focus the Wikipedia projects, so they will be read by classmates. These will be due the Monday following the week where the papers were discussed and talks were presented.

Before each class (due at 8AM on day of class), students will submit 1 question on each reading for the class. These questions will be culled by the professors into group discussion questions for the class breakout sessions. Extra credit will be awarded to selected questioners.

At the beginning of the second module, the class will be divided into teams covering the sub-items for each module. Some teams will be assigned peer-reviewing of other teams, so each student will only produce Wikipedia entries on 2 out of 3 modules (the first module will not induce a Wikipedia assignment). Motivating questions, examples, and potential roles for group members will be provided. Each team will be responsible for combining their short assignments, class discussions, and other material into Wikipedia entries (or major improvement of an existing Wikipedia entries). A typical Wikipedia page is roughly 2000 words, 2-4 figures, and up to 50 references. At the end of each module, the Wikipedia entries will be peer reviewed by the other teams. The original

wikipedia entries will be built and peer reviewed on canvas, but the final version, after revision to address peer reviews, will be uploaded onto the Wikipedia site.

For the final module (Other Approaches), each student will select an independent topic and independently develop their own (short) wikipedia entry.

7.1. *Calendar*

The main webpage for the class `http://fox-kemper.com/1950M` has the calendar with all assignment deadlines, readings, etc. There are four major modules, which each have multiple stages toward the final version of the Wikipedia page projects.

8. Canvas and Websites

The primary resource for this class is the webpage: `http://fox-kemper.com/1950M`. The class webpage is where all of your assignments will be announced, links to reading, etc. The second web resource is the canvas page for the class. All summaries, group projects, and peer reviews will be turned in through `http://canvas.brown.edu`.

You will want to familiarize yourself with Google Scholar (`http://scholar.google.com`) and the Web of Science (`http://apps.webofknowledge.com`). Both are free to you, and they will help you with your Wikipedia page creation.

9. Structure of Classtime

Each normal class will be broken down into three parts:
(a)Group breakout to discuss readings and selected, pre-submitted questions. (20 min)
(b)Presenter from each group leads presentation and discussion of question. (20 min)
(c)Lecture from faculty to warm up ideas on topic for next class (30 min).

If a guest speaker is present, the classtime will be reordered:
(a)Guest lecture. (30 min)
(b)Group breakout to discuss readings, selected, pre-submitted questions, and questions provided by guest lecturer. (20 min)
(c)Presenter from each group leads presentation and discussion of question. (20 min)

10. Expected Time for Activities

There will be four module assignments for this class.
- Class meetings (3 hours/week; 39 hours) [Grading: 10% Attendance, participation]
- Reading and Question Development (5 hours/week; 65 hours)
- Summary assignments (1 hours/week; 13 hours) [Grading: 15%]
- Two module team planning meetings (2×4 hours; 8 hours)
- Writing module projects (2×20 hours; 40 hours) [Grading: 40% Projects]
- Two module team wrap-up meetings (2×4 hours; 8 hours) [Grading: 10% Team participation]
- Peer reviews of 2 other teams (2×6 hours; 12 hours) [Grading: 15% Reviews of peers]
- Revise and resubmit projects. (2×4 hours; 8 hours) [Grading: 10% Revisions]
- Total: 189 hours [Grading: 100%]

10.1. *Why Wikipedia?*

This is an excellent opportunity to learn to write clearly and concisely for a broad audience, but in a technical and annotated manner. You can address the political, moral,

ethical aspects as well as the scientific, but the management of bias, balance, etc., is part of the process.

10.2. *Peer review*

Your group will peer review two other groups' work, which gives you practice:
•Learning to spot unfounded claims
•Learning how to properly support claims
•Learning to distinguish poor writing from poor thinking
•Learning to label equations, graphs, and numerical information understandably
•Learning about a broader swath of climate sciences than those isolated topics you choose for your own papers.

10.3. *Revisions and response to reviewers*

Groups will have an opportunity to respond to the peer reviews before uploading their pages to the world.

11. Policies

11.1. *Deadlines*

Because of the reviewing process, the scheduling of assignments is strict.

11.2. *Late arrival*

Because each class begins with either a group discussion or a guest lecturer, arriving on time is important. Persistent late arrivals will be penalized.

11.3. *Collaboration*

Many of the projects are group projects, and you will be polled about group dynamics to assess a grade. You will also have individual work in summarizing presentation and papers. This work must be your own, although you will often have opportunities to discuss the readings and presentations before writing.

A few other items.
•Attendance is expected. If you will miss a class, please let me know when and why so I can be sure you'll get any announcements, etc.
•Clothing and behavior (e.g., cell phone use) should be appropriate for a learning environment.
•Discrimination and harassment will not be tolerated.
•Please contact me if you have any disabilities that require accommodation.

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