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EPS 50: The Fluid Earth
Spring 2017

Instructors: Ann Pearson and Peter Huybers

Teaching Fellows: Elise Wilkes (elisewilkes@fas.harvard.edu) and Jenan Kharbush (jkharbush@fas.harvard.edu).

1st meeting: Haller Hall Tuesday, January 24th at 10am.

Time: Tuesday and Thursdays, 10:00-11:30am

Location: Haller Hall, (1st floor of the Geology Museum Building, room 102)

Web: https://canvas.harvard.edu/courses/21982

Section: To be determined.

Office Hours: (Ann, W 4:00-5:00; Elise, TBD; Jenan, TBD)

Textbook: A custom textbook is available at the Coop. It contains approximately half of the chapters of *Meterology Today* (C. Donald Ahrens, Robert Henson) and two-thirds of the chapters of *Oceanography, An Invitation to Marine Science* (Tom Garrison, Robert Ellis). The cost of the custom book is less than that of purchasing the two books independently, and both are the most recent editions, so we recommend that you purchase your text at the Coop rather than on-line. Other selected readings will be available for download from the course website, including a few chapters of the textbook *Earth's Climate, Past and Future* (William Ruddiman). **Two copies of the custom text are on reserve at Cabot Library.**

Overview: EPS 50 gives an overview of the mechanisms governing the oceans, atmosphere, and cryosphere and how they have combined to enable the study of climates past, present, and future. The course includes lectures, problem-solving laboratories, writing assignments, and exams.

Announcements

Feel free to write, call or visit any of us with questions or comments.

(Last updated January 19, 2017)

Administrative

Requirements: The course consists of 3 hours per week of lectures, 2 hours per week of laboratory/section with associated problem sets, short writing assignments, and 2 mid-term exams, each 1.5 hours long. Attendance at lectures and sections is required.

Prerequisites: This is an introductory course designed to be accessible to all students interested in the Earth Sciences. Background including introductory physics and chemistry at the high school or college level is helpful, but the relevant concepts will be covered in lectures and labs.

Grading: Based on participation (including climate discussion forum, below) (10%), problem sets (30%), the exams (40%), and the writing assignments (20%). Late homework and writing assignments will receive a 10% penalty per day.

Climate Discussion Forum: Students are expected to participate in an interactive discussion forum on the course web site. Each week, identify a climate-related topic in the news or other media, a journal, or even a discussion you heard in the subway, and make a brief post to the discussion board. Either frame your post as a question, or include a link to the article and a sentence to explain why the topic was interesting to you. We will begin each Thursday with a brief class discussion of the major issues of the week.

Collaboration policy

Discussion and the exchange of ideas are essential to doing academic work. For assignments in this course, you are encouraged to consult with your classmates as you work on problem sets, laboratories, and writing assignments. After discussions with peers, however, make sure that you can work through the problem yourself and ensure that any answers you submit for evaluation are the result of your own efforts. Written work you submit must be the result of your own research and written by you, reflecting your own approach to the topic. In addition, you must formally cite any books, articles, websites, lectures, or other material that you have used in your submitted work.

Integrity Policy

Schedule

1 Introduction & History of Earth's Climate [1 wk]

24 January – [Ann and Peter]

Course introduction and overview: History of Earth's atmosphere; what is a greenhouse gas?

- Reading: Allégre & Schneider, Scientific American, 2005. The evolution of Earth
- Reading (***optional***): Lovelock & Margulis, Tellus 1974. Atmospheric homeostasis by and for the biosphere: The Gaia hypothesis

26 January – [Ann]

When it was cold…and when it was warm: Understanding climate on multiple timescales.

- Reading: Meteorology Today, Chapter 18, Earth's Changing Climate

2 Atmosphere [2 wk]

31 January – [Peter]

Heating the Earth: Radiative balance and consequences of imbalance.

- Reading: Meteorology Today, Chapter 1, Earth and Its Atmosphere
- Reading: Meteorology Today, Chapter 2, Energy: Warming Earth & Atmosphere
- Reading: Oceanography, Chapter 8.1-8.3, Circulation of the Atmosphere

02 February – [Peter]

What is El Niño (Part I)? Pressure, winds, and Hadley circulation.

- Reading: Meteorology Today, Chapter 8, Air Pressure and Winds
- Reading: Meteorology Today, Chapter 10, Wind: Global Systems
- Reading: Oceanography, Chapter 8.4, Circulation of the Atmosphere

07 February – [Ann]

Why does it rain? Clouds, climate, and feedbacks.

- Reading: Meteorology Today, Chapter 6, Stability and Cloud Development
- Reading: Oceanography, Chapter 6.4-6.5, Water and Ocean Structure

09 February – [Ann]

Special weather: Tornadoes, monsoons, and hurricanes. Heat transport.

- Reading: Meteorology Today, Chapter 10, Wind: Global Systems
- Reading: Oceanography, Chapter 6.5, Water and Ocean Structure
- Reading: Oceanography, Chapter 8.4-8.5, Circulation of the Atmosphere

3 Ocean [3 wk]

14 February – [Ann]

Introduction to Ocean Chemistry: Thermohaline circulation and the composition of seawater; major water masses; the Equation of State.

- Reading: Oceanography, Chapter 6.1-6.6, Water and Ocean Structure
- Reading: Oceanography, Chapter 7.1-7.3, Ocean Chemistry
- Reading: Oceanography, Chapter 9.6, Circulation of the Ocean

16 February – [Ann]

Introduction to Ocean Dynamics *i*: Coriolis force and geostrophic balance.

- Reading: Oceanography, 8.3, Circulation of the Atmosphere
- Reading: Oceanography, Chapter 9.1-9.2, Circulation of the Ocean

21 February – [Ann]

Introduction to Ocean Dynamics ii: Ekman layers, gyre circulations, and ocean currents.

- Reading: Oceanography, Chapter 9.1-9.4, Circulation of the Ocean
- Reading: Law et al., Plastic accumulation in the North Atlantic Subtropical Gyre. *Science* 329:1185-1188.

23 February – [Ann]

The Timescale of Ocean Mixing: Anthropogenic tracers, radiocarbon, ocean-atmosphere mixing.

- Reading: Tracers in the Sea, Chapter 5, pages 236-243 and 245-252 (skip rate of continental runoff).

28 February – [Ann]

Production and Nutrients: What is a nutrient and how is it distributed? Redfield Ratio; understanding the limits on ocean fertilization.

- Reading: Oceanography, 6.8, Water and Ocean Structure
- Reading: Oceanography, Chapter 14.1-14.6, Primary Producers

02 March – [Ann]

What is El Niño (Part II)? Overturning and the El Niño Southern Oscillation

- Reading: Oceanography, Chapter 9.4, Circulation of the Ocean
- Reading: McPhaden et al., (2006) ENSO as an integrating concept in Earth science. *Science* 314:1740-1745

07 March – [Ann]

Midterm Exam #1, in class

3 Carbon Cycle and Climate Forcing [3.5 wk]

09 March – [Ann]

Introduction to marine geology & ocean sediments: Plate tectonics, ocean basins, rock cycle; types and age of sediments.

- Reading: Oceanography, Chapter 3.6-3.10, Earth Structure and Plate Tectonics
- Reading: Oceanography, Chapter 4.1-4.4, Ocean Basins
- Reading: Oceanography, Chapter 5.1-5.5, Sediments

————————————11-19 March, Spring Break————————————

21 March – [Ann]

The Stable Geologic Carbon Cycle: Urey feedback; inorganic carbonate chemistry; the ocean carbon system.

- Reading: Oceanography, Chapter 7.4, Ocean Chemistry
- Reading: Earth's Climate (Ruddiman), Chapter 4

23 March – [Ann]

Hot and cold Earth: Proxy records – how do we know the past? Measuring paleotemperature; ice core and other CO2 records.

- Reading: Oceanography, Chapter 5.6-5.9, Sediments
- Reading: Mann M and Jones PD (2003). Global surface temperatures over the past two millennia. *Geophysical Research Letters* 30: doi:10.1029/2003GL017814

28 March – [Ann]

Methane and other GHGs: More than just CO2…

- Reading: Earth's Climate (Ruddiman), Chapter 11, Orbital-Scale Changes in CO_2 and CH_4

30 March – [Ann]

Present and Future Carbon Cycle: Stable or Unstable? Feedbacks and imbalances.

- Reading: TBD

04 April – [Peter]

The Unstable Ice Age Cycle: Milankovitch cycles Part I.

- Reading: Meteorology Today, Chapter 3, Seasonal and Daily Temperatures
- Reading: Meteorology Today, Chapter 18, Earth's Changing Climate

06 April – [Peter]

The Unstable Ice Age Cycle: Milankovitch cycles Part II.

- Reading: Earth's Climate (Ruddiman), Chapter 8, Astronomical Control of Solar Radiation

5 Cryosphere [1 wk]

11 April – [Peter]

What is a glacier? Properties of grounded and floating ice

- Reading: Glacier Mass Balance: http://www.antarcticglaciers.org/modern-glaciers/introduction-glacier-mass-balance/

13 April – [Peter]

Greenland and Antarctica: Maintenance and causes of change

- Reading: Earth's Climate (Ruddiman), Chapter 10, Insolation control of ice sheets.
- Reading: http://www.antarcticglaciers.org/glaciers-and-climate/shrinking-ice-shelves/pine-island-glacier/
- Reading: http://www.antarcticglaciers.org/glaciers-and-climate/ice-ocean-interactions/marine-ice-sheets/

6 Special Topics [1 wk]

18 April – [Ann]

Sea Level: Past and future oceans; how soon will Florida be underwater?

- Reading: Oceanography, Chapter 3.4, Earth Structure and Plate Tectonics
- Reading: Oceanography, Chapter 12, Coasts
- Reading: Fairbridge RW (1960) The changing level of the sea. *Scientific American* 5:70-79.

20 April – [Ann and Peter]

Climate risks and hazards: Open Forum and Discussion

25 April

Midterm #2, in class

3 May (Last Day of Reading Period)

Final writing assignment due