Great Papers in the Earth Sciences

FAS course web page: Great Papers, EPS 281r
(Spring 2017)

Instructors: Peter Huybers (phuybers@fas.harvard.edu) and Eli Tziperman (eli@seas.harvard.edu).

TF: Dan Cusworth (dcusworth@fas.harvard.edu)

Day & time: Class meetings are from Wednesday 3-5. Groups preparing presentations for following week will continue from 5-6pm.

Location: Geological Museum room 413

1st meeting: TBA

Bibliography: Papers are linked from this document.

this document: syllabus_EPS281_2017.pdf

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

1 Administrative

Prerequisites: This is a basic introductory breadth course and should be accessible to all Earth and Planetary Science graduate students.

Requirements: Apart from reading all assigned papers, students prepare presentations on one or more of the topics to be covered during the course based on the papers posted on the course web page and lead a discussion during class. Students not part of the presenting group turn in one page (12pt, single spacing) describing the objective, approach, and main results of the paper, along with an argument for what does, or does not, make it great. This one-page report is turned in at the beginning of the class.

Guidelines for student presentations

Each subject will require two presentations by the students leading the corresponding discussion. You are asked to organize into groups of 2-3 for this purpose.

The first presentation is about 5-slides, 10 minute long, and has a minimum font size of 24. It is given the week before the subject is discussed in class. The purpose of this brief presentation is to help the other students understand the more difficult aspects of the reading material.

The second presentation is about 30-slides long, has a minimum font size of 24, and is used during the discussion. The presentation is organized beginning with some background for the other students, but gets to the actual paper within 5 to 6 slides. All relevant figures and equations are included from the paper, along with explanations and guiding questions.

The purpose of this presentation is to promote discussion, as opposed to supporting a lecture. Indeed, an indication of a successful presentation is that not all ∼30 slides are presented because discussion absorbs the class time. All member of the presenting group should be versed in all parts of the presentation, and group members will switch presenting between each slide.

Grading: Based on presentations, discussion, participation, one page summaries, and (mandatory) attendance.

2 Overview and goals

A survey of breakthrough papers in all of the earth sciences, as well as modern papers that put the classics in perspective. Students engage in the material through reading, presentation, and discussion. The course has several goals. First, to engender an understanding and appreciation of major breakthroughs in our field. Second, to develop skills in presenting and discussing scientific results. And, last but not least, to improve understanding of what constitutes great science.

3 Syllabus

Below is a sketch for the topics to be covered each week, with alternate possible subjects indicated by bullets. Blue links below lead to the reading material for each lecture.

- *• **Jan 25th** Introductory lecture and discussion

Geophysics

- *• **Feb 1st** Earth age and thermal history (geophysics): read the wikipedia entry about the age of the Earth, and then the England et al (2007) historical review and the short address by Kelvin 1869 ("On geological dynamics"). Finally, read our classic papers: the exchange between Perry and Kelvin (specifically the file perry_kelvin_nature_January_1895.pdf). Optional: see beginning of the two Lord Kelvin piece from 1868 to learn more about Kelvin's opinion of geologists. For many more Kelvin papers, see here.

- *• **Feb 8th** Plate tectonics - sea floor spreading and magnetic reversals (geophysics). Read the few pages from the book by Wegener, then the brief wikipedia entry on the Vine-Matthews-Morley hypothesis, and the wikipedia entry on plate tectonics. Then read Hess (1962) with the suggestion of convection cells driving sea floor spreading and prediction of sea floor magnetic patterns. Then read Vine (1966) for the actual observation and interpretation of the magnetic reversals. Optional: Vine and Matthews (1963)

- • Pratt and Airy Isostasy

• Plate tectonics - rigid plate motion on a sphere (geophysics). Read first the two wikipedia entries then the few pages from the book by Wegener, then Morgan 1968 discussing tectonic plate motion on a sphere. [Optional: The Morgan paper has an interesting history: see the LePichon note that tells the story of why the McKenzie-Parker paper came out first although Morgan came up with the idea (and submitted the paper) before them. McKenzie-Parker 1967 and the original 1967 Morgan notes in the file MorganTectonoph91.pdf; Wilson 1965, which introduces transform faults.]

• Polar Wander (geophysics). Gold (1955), Goldreich and Toomre (1969) and others to be added.

• Earth Dynamo (geophysics). Read the two Wikipedia entry, then the Larmor (1919) paper and then only the highlighted parts of Bullard (1949) ?.

• Earth's interior structure. Read the introductory text from J. L. Ahern, then the classic paper by Oldham (1906), and finally the notes by Victor Tsai.

• Whole-mantle versus layered mantle convection (geophysics). Birch (1952) and others to be sorted out among papers in sources directory.

Geology

*• **Feb 15th** Extinctions and the KT impact hypothesis (geology). Read (A) wikipedia entry on Chicxulub crater, (B) wikipedia entry on KT boundary, (C) Alvarez et al (1980), (D) Raup and Sepkoski (1982).

• Glacial cycles (geology, climate) Read the Wikipedia entry about Milankovitch cycles (changes in the orbital parameters of the earth around the sun which affect climate). Next, read our classic paper by Hays, Imbrie and Shackleton (1976). Read the excerpts from the book "Ice Ages Solving the Mystery" by John Imbrie and his duaghter, Katerine Imbrie, (p113-140) for a colorful description of the Milankovtich theory and its initial acceptance, rejection, and subsequent re-acceptance. [Optional: For the personality perspective in this case read the wikipedia entry about Louis Agassiz and the article by E.P. Evans in the file "did-agassiz-discover-glacial-cycles.pdf". Note the contrast between (1) his objection to Darwin's ideas, his "work" on "Racial classification", and the suspicion that he may have stolen the glacial cycle idea from someone else, and (2) the fact that he was such a beloved, admired and influential scientist (especially wikipedia entry about him).]

• Snowball, Budyko-Sellers (geology, climate). Read the two page Kirschvink (1992) paper (that's our classic this time) and then Hoffman et al (1998). Finally, read the 1 page notes file energy_balance_0d for the Budyko-Sellers model which predicted the existence of a snowball earth in 1969.

Ocean and atmosphere dynamics

• **Feb 22nd** Chaos and weather prediction. Read the brief introduction to chaos and then the wikipedia entry about fractals (better read this one on-line, for the nice animations in wikipedia), and then Lorenz 1963 paper itself. Note that Lorenz does not use the terms "chaos" or "fractals" which were only coined later, yet but he clearly understands both. For a nice on-line fractals demo, see here.

*• **Mar 1st** Abyssal Recipes, Munk

*• **Mar 8th** Stratospheric circulation Brewer-Dobson circulation. Read Brewer (1949) and Cordero et al chapter 6.3 (figures are available here). Optional: An outline of the dynamics of the B-D circulation is given in the notes, with references to relevant sections and equations in the Vallis textbook.

• Ferrel cell (atmospheric dynamics).

• Abyssal ocean circulation and deep western boundary currents. (physical oceanography). Read the Stommel-Arons (1960) paper that predicted a deep southward current under the northward flowing Gulf Stream, and the observational verification paper by Swallow and Worthington (1961).

• Thermohaline circulation (physical oceanography). Read the Rahmstorf (2006) encyclopedia entry first, then notes on the simplified Stommel-like Taylor model, and finally the classic Stommel (1961) paper.

• The Gulf Stream (physical oceanography) Read Stommel (1948).

• Hadley cell (atmospheric dynamics). Read (A) wikipedia entry, (B) Hadley (1735), (C) Showman (2009) to end of first paragraph on p 12.

• ENSO (Climate dynamics). Bjerknes paper.

Geochemistry

*• **Mar 22nd** Silicate weathering and CO2 (geochemistry) Read the papers by James et al (1981) and Berner et al (1983). See if Francis wants to join us.

*• **Mar 29th** Geothermal vents and origin of life (geobiology). Read Schulte (2007) and then Corliss et al (1981). The optional on-line lecture in the above link is very helpful as well.

• Whole-mantle versus layered mantle convection (geochemistry). Relevant early paper is O'Nions et al. (1979). Closure is obtained by Alegre, Hofmann and O'Nions (1996).

• Stable isotopes and paleoclimate (geochemistry) Read the two wikipedia entries on $\delta^{13}C$ and $\delta^{18}O$, and then the Urey (1948) and Epstein et al (1953) classic papers. For essentially the current interpretation of marine $\delta^{18}O$ records, see Chappell and Shackleton (1986).

• Evolution; Darwin.

Planetary

*• **Apr 5th** Origin of the oceans (Planetary sciences). The debate here is between the "early delivery" camp (water came with the planetesimals that accreted to make the Earth), vs the "late veneer" suggesting that appreciable fraction of the volatiles came later in comets. Read the wikipedia article, then the Robey (1951) classic and finally the Deming (1999) representing the alternative theory.

*• **Apr 12th** Faint young sun paradox for early Earth and Mars (Planetary sciences).

• Origin of the Moon (Planetary sciences). Read the wikipedia article and then Careron and Ward (1976) and Hartmann and Davis (1975). Optional: the different hypotheses are more clearly presented in the papers by Cameron (1986) and Canup and Ashphaug (2001) that are in the "more" directory, which you are encouraged to read.

• Evolution of the solar system (Planetary sciences).

• Runaway greenhouse of Venus atmosphere oceans (Planetary sciences).

Atmospheric chemistry and radiation

*• **Apr 19th** 1. Dole effect; or 2. Keeling O2-CO2 closure

• Ozone hole (atmospheric chemistry). Read the Wikipedia entry on Ozone depletion, and then the two classic papers: Molina and Rowland (1974) who predicted the ozone hole and its formation mechanism, and Farman, Gardiner and Shanklin (1985) who later observed it. Finally, to get an idea of the policy process that led to the successful ban on CFCs, read the Wikipedia entry on the Montreal Protocol and the Greenpeace summary of the DuPont position on CFCs and ozone hole.

• Greenhouse effect (climate). Read (A) from the IPCC fifth assessment report chapter 8: executive summary (p 661-663), first two paragraphs in section 8.1 p 664, then box 8.1, FAQ 8.1 and section 8.3.2.1; (B) Arrhenius (1896). Optional: Crawford 1997 with a modern-day explanation of the Arrhenius paper.

• Reactivity of OH (atmospheric chemistry) Read the wikipedia entry and the two brief introductory web pages from www.atmosphere.mpg.de and www.niwa.cri.nz, then our classic paper by Levy (1971); and then read pages 147-149 in the AR4 IPCC report (section 2.3.5); optional: paper by Prinn in the `more/` directory.

• Keeling-curve (atmospheric chemistry) Read Keeling et al. 1976 where the upward trend in atmospheric CO_2 is documented.

Others

• Gaia! (ecology). Read the wikipedia entry, pages 1-8, until but not including the "History" section. Then read Watson and Lovelock (1983), you may find the Gaia pdf notes on the course web page to be helpful in understanding this paper. Then read Kirchner (2002) with criticism of Gaia. In your report, in addition to the usual discussion, describe one example of a biological feedback that regulates the physical environment. [Optional: Lovelock and Margulis (1973).]

• Student selected topics. Each group selects a great paper not discussed earlier and presents its significance to the class. These presentations should be ~10 slides long, take about 30 minutes, and survey the findings in the paper and discuss what makes it great.

Modern Classics

*• **Apr 26th** Each group is responsible for identifying a paper published in the last 20 years that they think will become a classic. Make a short 4-slide presentation describing (slide 1.) what makes for a great paper, (slides 2-3.) what this paper shows, and (slide 4) why its a great paper.