GEOL 412 – Oceans, Climate & Environment – Spring 2017

Class Time: **11-12.20pm Monday and Wednesday**, **Location ZHS 200**
Instructor: **Professor Sarah Feakins**
ZHS 223F, 213 740 7168, feakins@usc.edu **(preferred)**
Office hours: 10-12am Fri, or by appointment

Text: **Global Physical Climatology 2nd edition**, by Dennis L. Hartmann, ISBN 0-12-328530-5, Academic Press, London. Available in USC bookstore, or to rent or buy from Amazon. Additional readings provided or accessible through USC libraries.

Recommended (not required) preparation: CHEM 105*bL,* MATH 126, PHYS 151*L*/135*abL, GEOL 107/150.*

Midterm Exam: Wednesday, March 8th, 11-12.20pm ZHS 200
Final Exam: Wednesday, May 3rd 11-1pm, ZHS 200

Grading: Assignments 20%; Midterm Exam 20%; Research Project 30%; Final Exam 30%
Units : 4

Course Objectives and Outcomes: This course is intended to provide a foundation for understanding the Earth's climate and ocean system, and is geared towards undergraduate majors and minors in Earth Sciences and Environmental Studies. Undergraduates from other disciplines and graduate students seeking a foundation in climate science are also welcome. We will learn about the fundamental properties of the ocean and atmosphere. We discover the key factors that control climate and how these have varied through time. We will explore approaches to climate, ocean and environmental science including an overview of modern observations and modeling and 'proxy' climate records that can extend our knowledge beyond the short instrumental period. We will learn about how the climate system works, and how it varies and consider how climatic and environmental variability influences societies in the past, present and future. You will develop your scientific skills though assignments building towards individual research projects that also hone a range of presentation skills.

Topics:

Week 1: **Introduction to Climate and Ocean Science**
Introduction to the climate system. The Atmosphere as an efficient communicator, the Ocean as a heat storage and transport mechanism. Overview of the course.
Reading: GPC chapter 1

[Professor Feakins is unavailable Monday night-Thursday night inclusive in week 1 as she is serving on the International Ocean Discovery Science Evaluation Panel at the Scripps Institute of Oceanography.]

Week 2: **MLK day no class**

Planetary Scale Energy Budgets
Climate at the planetary scale. Solar emissions: Plank, Wien and Stephan Boltzman laws of blackbody radiation. Insolation received at the Earth. Temperature of emission of the Earth. Energy Budget of the Planet. Consideration of other planets in our solar system; discussion of other solar systems.
Reading: GPC 2.1-2.6 and 3.1-3.4 and 4.1, 4.4 (albedo)

Week 3: **Atmosphere – Greenhouse Gases**

Climate at the planetary scale: Role of Greenhouse Gases. Principals of absorption and emission in gases. Temperature at the surface of the Earth. Planetary Energy Balance for a planet with an atmosphere. Construction of a 1D model of earth's climate considering a 1 layer atmosphere. Climate sensitivity to GHGs.
Reading: GPC 2.5, 3.5, 3.8, Petit et al., 1999 Vostok GHG record.

Atmosphere – Latitudinal variations

Insolation variations with latitude. Obliquity of the Earth's axis and seasonality. Latitudinal variations in energy budgets. Ocean and atmospheric heat transport. General circulation of the atmosphere, Trade Winds, ITCZ, Westerlies. Coriolis Effect.
Reading: GPC 2.7-2.9, 4.7-4.9, 6.1, 6.3, 6.5

Week 4: **Atmosphere – Moisture in the Atmosphere**

We start with watching a simulation of water vapor and precipitation during the course of the year for the planet, make and discuss observations. Then move onto a discussion of the fundamental rules governing moisture in the atmosphere: Claussius-Clapeyron Relation. Detection of moisture in the atmosphere (visible, IR). Moisture convection and lateral transport and latent heat flux.
Reading: GPC 3.9, 3.10, 3.12

Atmosphere – Hydrological Cycle

Fundamentals of the global hydrological cycle, quantification of components, fluxes. Global and precipitation and evaporation patterns. Consideration of regional precipitation and potential evaporation seasonality and implications for water availability. Case study California's water: importance of snowpack, climate change.
Reading: GPC 5, Californian climate change report handout.

Week 5: **Atmosphere – Monsoons**

Seasonality, land-sea temperature contrasts, sea breezes, monsoons, ITCZ migration. Examples: Asian Monsoon and societal issues; West African Monsoon; North American Monsoon. Santa Ana Winds as an example of an episodic reversal of prevailing winds.
Reading: GPC 6.5 (large scale circulation patterns relate to multiple lectures in weeks 3-6, including the Monsoons topic)

Week 5: **Hurricanes**

Necessary conditions for hurricane formation. Limitations on modeling hurricanes: scale issues, hurricane genesis, hurricane size and strength, hurricane tracks. Consideration of what can and can't be well resolved in existing models. Model skill. Scope for improvement in seasonal predictions. Societal issues.
Readings: Emanuel, K., 2005, Increasing destructiveness of tropical cyclones over the past 30 years, Nature, doi:10.1038/nature03906. Tropical Storm Risk Seasonal projection issued December of preceding year for the upcoming summer storm season.

Atmosphere – Lapse Rate Games

Climate calculations using lapse rates, using simple graphing techniques with an emphasis on back of the envelope estimates, with discussions of the magnitude of

uncertainties in various assumptions. Instability and stability in the atmosphere. Katabatic winds and polynyas, Antarctic Example. Temperature inversions, local scale Los Angeles and smog, large scale tropopause examples. Orographic precipitation, Sierra Nevada example. Monsoon circulation, Indian example.
Reading: *GPC 3.10, especially figures 3.16, 3.17 and 3.19 on lapse rates, GPC 6.5 (also listed for monsoons lecture)*
Student presentations: *Brief oral proposal of your independent study topic.*

Week 6: **President's Day no class**

Ocean – Surface Ocean Circulation
Major ocean currents, and features. Controls on ocean circulation: atmospheric circulation, Coriolis effect, boundary effects. Winds, wind drag and Ekman transport, direction and speed of ocean currents. Gyre circulation, boundary currents, ocean dynamic topography, geostrophic flow. Eddies. Gulf Stream, California Current.
Reading: *GPC 7.1, 7.4 and optional 7.5*

Week 7: **Ocean – Properties of Water**
Dissolved solids, salinity units, means of measurement, differences in riverine inputs of freshwater between ocean basins, salinity as a conservative tracer of deep water masses. Temperature and potential temperature. Controls on density. Density stratification in the oceans. Dissolved gases and air-sea gas exchange.
Reading: *GPC 7.2*

Ocean – Deep Ocean Circulation
T, S in the deep ocean, identification of major water masses. The Thermohaline circulation. Ocean circulation in the past
Reading: *GPC 7.6, 7.8*

Week 8: **Ocean - influence of ocean life on climate**
Where is life, what is it doing? Carbon cycle, biological pump concepts. Satellite studies, in situ sediment traps, sedimentary records, geological time.

MIDTERM EXAM (Wednesday 8th March, before a well-deserved spring break!)

Week 9: ****March 12-19 SPRING BREAK****

Week 10: **Ocean – El Niňo Southern Oscillation ENSO**
History of ENSO observations, ocean SST, SSTa, thermocline; SLP and Southern Oscillation, Bjerknes feedback and delayed oscillator, teleconnections and impacts, ENSO and paleoclimate.
Reading: GPC 8, especially 8.3

Forcings: Natural climate variability: Sunspots, Volcanoes
We consider 2 means of altering climate with different temporal characteristics. 1.The Sun and its variations in radiative fluxes through time: Sunspots, faculae, UV spectrum. 2. Volcanic aerosols, past reconstructions. Historical, satellite and proxy evidence for past variations and implications for climate.

Reading: GPC 12.1-12.4

Week 11: **Forcings: Anthropogenic climate change**
Human induced climate changes, greenhouse gases, aerosols, climate feedbacks.Signs of climate change: temperature, ice and sea level.
Reading: GPC 13

Forcings: Orbital pacing of climate change
History of scientific discovery of glacial interglacial cycles, oceanography and oxygen isotopes, variations in the Earth's orbit.
Reading: GPC 12.5-12.6

Week 12: **Student Presentations:** *Powerpoint presentation of your independent study project with peer review*

Week 13: **Student Presentations:** *Powerpoint presentation of your independent study project with peer review*

Week 14: **Past Climate Change: Marine Proxies**
Ocean sediments; geochemical approaches to reconstructing past conditions including oxygen isotopes, Mg/Ca, biomarkers; variations in deep sea and sea surface temperature, ice volume and other questions.
Reading: GPC 9

Past Climate Change: Terrestrial Proxies
Continental proxies and archives: tree rings, pollen, biomarkers, lake cores, ice cores, speleothems, geomorphology.
Reading: GPC 9

Week 15: **Mechanisms 1: Climate sensitivity and feedback mechanisms**
Forcings, non-linear responses, equilibrium states, positive and negative feedbacks.
Reading: GPC 10

Week 16: **Mechanisms 2: Climate models**
Why do we need models? Testing cause and effect. Hierarchy of model type. How to use models to answer climate science questions. Example applications.
Reading: GPC 11

Term Paper due (Last Class): *Submit written report on your independent study projects*

Additional Information:

Grading: Your grade is based upon assessment of numerical, graphical and written homework assignments, midterm and final examinations (cumulative) and your research project (assessed by the quality of both your oral and written presentations). Final grades are based upon the total calculated from: Assignments 20%; Midterm exam 20%; Research Project 30%; Final exam 30%.

Research projects: The USC Earth Science department considers that individual research projects are a valuable part of the education in our program: “These are effective learning tools that require students to apply what they have learned and synthesize a body of knowledge, without having a proscribed “correct” answer. They have been effective in inspiring some students to continue on to do directed research projects or acquire a part time job with faculty engaged in funded research projects.” More broadly they allow you the skills to direct your own learning, which is very good preparation for graduate degree programs and more broadly offers lifelong benefits in terms of your personal fulfillment and career development.

Examinations: The midterm examination and the final exam will evaluate student comprehension of the lecture and readings (textbook and assigned readings); they will emphasize material covered in lecture. The final exam is cumulative. Exams will include calculations, diagrams, short and long answer questions and will emphasize comprehension of the concepts, rather than rote memorization.

Missed Examinations: If you have to miss an examination because of illness or an academic conflict, you must inform the Professor by email **in advance**, and provide documentation. Make-ups of examinations will, in general, NOT be permitted except for extraordinary circumstances (e.g., documentable conflicts with other USC-related commitments).

Academic Integrity: University policies on academic dishonesty are printed in SCAMPUS and SJACS, see http://www.usc.edu/student-affairs/SJACS. USC policies on academic dishonesty are strict and the minimum punishment is a “0” on the assignment. This is an upper level course in which we explicitly cover acknowledging and referencing sources. Copying and pasting answers from websites such as Wikipedia constitutes plagiarism - don’t do it. Remember, learning is an active process!

Disability Services: Students requesting academic accommodations based on a disability are required to register with Disability Services and Programs (DSP) each semester. A letter of verification for approved accommodations can be obtained from DSP when adequate documentation is filed; *please be sure the letter is delivered to the professor as early in the semester as possible, and at least 2 weeks prior to the first midterm*. DSP is open Monday-Friday, 8:30-5:00. The office is in 3601 Watt Way, Grace Ford Salvatori Hall 120 and the phone number is (213) 740-0776.

About the Instructor:

Sarah Feakins is an Associate Professor of Earth Sciences at USC, where she has been a member of faculty since 2009. Previously, she was a NOAA Climate and Global Change Postdoctoral Fellow at the California Institute of Technology from 2006-2008 working on proxy calibration in isotope biogeochemistry. She obtained her PhD (Geology) in from Columbia University's Department of Earth and Environmental Sciences at Lamont-Doherty Earth Observatory in 2006 with a thesis reconstructing paleoenvironments of northeast Africa during the Neogene and related to human origins. She obtained a first-class degree and was top of her year in Geography at the University of Oxford (1998-2001). At USC since 2009, she has taught 107, 412, 566 and 575, while running a research program from the Leaf Wax Lab in SHS 460, funded by the US National Science Foundation, American Chemical Society and other sources with a team of graduate and undergraduate students earth.usc.edu/feakins/people/. She has a passion for engaging students in large-scale thinking about the Earth and in honing expertize in biogeochemistry needed to push forward analytical frontiers to uncover evidence for past environments to reach a deeper understanding of the climate system, the evolution of our species and our future trajectory. While some build models, mostly trained in the modern to predict the future, my research approach makes detailed measurements about the past to see how the climate system has operated at warm times in the past to provide a geological window into our future. How do precipitation patterns and ecosystems respond as the climate shifts? Earth history provides real-world realizations that constrain a wider realm of what's possible. We need to bring all our powers of reasoning to bear on understanding our place in the climate system. This upper-division climate course seeks to provide the inspiration and the fundamentals to take you there: as ocean/atmosphere trained earth scientists, ready for advanced study and research, environmental risk and consultancy, governance and other careers.

My research webpage is here:
http://earth.usc.edu/feakins/

My publications can be found here:
Research Gate, Google Scholar.

I periodically post research/climate news articles of interest here:
https://twitter.com/SFeakins

To contact me:
feakins@usc.edu