ENVP U6115: Climatology (Summer 2022)

Instructor

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- Office Hours: available during lab sessions or by appointment

Teaching Assistants

Abhinav Banthiya, ab5472@columbia.edu
- Office Hours: Thursday; 2:30pm - 4:30pm Schermerhorn DEES student lounge (5th floor)
Katie Parker, kgp2113@columbia.edu
- Office Hours: Friday; 2:30pm - 4:30pm Schermerhorn DEES student lounge (5th floor)
Nevin Singh, nts2115@columbia.edu
- Office Hours: Wednesday 2:30pm - 4:30pm; online (email for zoom link)

Class Meeting Schedule

Lecture: 9am-12pm 413 IAB
Lab: 1-3:30pm and 3:30-6pm SCH 417

Class & Lab Description

Course Description

This course provides an introductory survey of the Earth's climate system. We will study the salient properties of climate and its characteristic space and time variations. The physical laws governing these variations will be explained to build a rudimentary understanding of the natural phenomena of climate as well as the impact of human industrial and agricultural activities.

Course Outline

The approach of the course follows a general sequence of themes that will: (1) define climate and the difference between climate and weather; (2) explain the source of the Earth's heat energy, how temperature near the surface and aloft are determined, and how the observed seasonal and spatial variations are created; (3) introduce the various motion systems in the atmosphere and ocean and their governing physical laws; and (4) address the contemporary issues of environmental change on different time-scales and of human-induced vs. natural variability.

Daily Activities: Morning sessions will present the key concepts for the week in lecture-format, but will also include discussion of reading materials, and short group exercises. The schedule below is a preliminary outline of the semester. Reading assignments are provided and should be completed before the stated lecture date. Additional reading or reference material may be suggested during the course of the lecture. Laboratory sessions will involve both hands-on and minds-on exercises that will require either individual or small group work/reporting.

Session 1: Tuesday, June 6. —THE PLANETARY ENERGY BALANCE

Read: Mathez & Smerdon, ch 5 (all pages), ch 6 (p 163-171)

Lecture 1: Driving Climate - The Sun, Energy and Light: What is climate? Light and energy. Solar constant. The inverse square law. Incoming solar radiation at the top of the atmosphere. Albedo. Why do we have seasons?

Lecture 2: The Green House Effect and the Radiation Balance of the Earth: Shortwave radiation. Longwave radiation. Stefan-Boltzmann law. Energy balance at the top of the atmosphere. Greenhouse gases and greenhouse effect. Atmospheric emissivity. Radiative forcing.

Lab 1: Introductory material (how to write a lab report); The Earth's Radiation Budget I

Session 2: Tuesday, June 13 —CLIMATE OF A SINGLE ATMOSPHERIC COLUMN

Read: Mathez & Smerdon, ch 1 (p 13-28)

Lecture 3: The Energy Balance at Earth's Surface, the Energetics of Water Phase Changes, and the Hydrological Cycle: The transfer of energy from the surface to the atmosphere through dry and wet air. Surface energy fluxes and surface energy balance. The spatial patterns of the various components of Earth's energy balance and the implied need for ocean and atmospheric circulation to achieve energetic equilibrium. Evaporation. Condensation/Precipitation. Measuring water vapor content in the atmosphere. The Clausis-Clapeyron equation and its implications for climate change.

Lecture 4: Vertical Structure of the Atmosphere: Pressure and Temperature: Stratosphere and ozone. Antarctica ozone hole. Montreal Protocol on Substances That Deplete the Ozone Layer. Atmospheric pressure. Hydrostatic balance. Tropospheric lapse rate, dry adiabatic lapse rate and an introduction to atmospheric stability.

Lab 2: The Surface Energy Budget and the Hydrological Cycle

Session 3: Tuesday June 21 —WIND AND CLIMATE ZONES

Read: Mathez & Smerdon, ch 1 (p 29-41)

Lecture 5: General Circulation of the Atmosphere, Part 1: Zonal, meridional and vertical winds. Geopotential height. Hadley circulation, its energy transport, and its relationship with the Inter-Tropical Convergence Zone and surface aridity.

Lecture 6: General Circulation of the Atmosphere, Part 2: Coriolis effect. Pressure gradient forcing. Geostrophic balance. Frictional destruction of geostrophic balance. Polar front, polar jet stream, Rossby waves, poleward energy transport beyond the Hadley circulation.

Lab 3: Atmospheric circulation and the effects on life

Session 4: Tuesday June 27 —THE CLIMATE'S FLYWHEEL: THE OCEAN

Read: Mathez & Smerdon, ch 2 & 3

Lecture 7: Ocean Circulation and the Impact of the Ocean on Climate: Ekman spiraling and Ekman transport. Ocean gyres. Wind-driven ocean circulation. Warm western boundary currents. Cool eastern boundary currents. Ocean upwelling and downwelling. Density-driven ocean circulation. Thermohaline circulation and its energy transport.

Lecture 8: El Niño - An Atmosphere-Ocean Phenomenon: The Pacific Walker circulation. El Niño and La Niña. Atmospheric and oceanic processes during El Niño and La Niña events. Bjerknes feedback. How El Niño and La Niña affect the U.S. climate?

Lab 4: The Climatic Impacts of El Niño

Session 5: Monday, July 3 —CLIMATE CHANGE, THEN AND NOW

Read: Mathez & Smerdon, ch 4 (p 101-120), ch 7, ch 8, ch 9, ch 11

Lecture 9: Climates of the Past: Chemical weathering. Positive feedback. Negative feedback. Proxies for the past climates. Orbital variations and the Milankovitch cycles.

Lecture 10: Observed Climate Variability, Climate Models: Observed climate records: how are they collected and what do they tell us about climate over the past 150 years? Forced climate change and unforced internal climate change/variability. What are climate models, how are they constructed, and what do they tell us?

Lab 5: The Global Temperature Record and Regional Impacts

Final Examination: Friday, July 7, 9-12PM

Required Reading

"Climate Change: The Science of Global Warming and Our Energy Future, 2nd edition" by Edmond Mathez and Jason Smerdon. All the figures are also available online: https://cup.columbia.edu/extras/climate-change-the-science-of-global-warming-and-our-energy-future-second-edition-supplemental-materials

Optional Readings For Your Interests

"The Earth System" by Lee R. Kump and James F. Kasting, Robert G. Crane, Prentice Hall, 3rd edition, 2009 (432 p): A basic earth system science book (of which climate is just one part). We use this book in the DEES undergraduate "Climate System" course. It provides a good background on the basics of the Earth system with helpful graphics. The book also provides

useful chapter summaries and review questions that you can use to test your understanding of the course. You can request that the library scan for you the relevant chapters:
https://clio.columbia.edu/catalog/11363430

Other great books on the subject of climate change are available as ebooks from the library:
https://clio.columbia.edu/catalog/12457965 (David Archer: Global warming: understanding the forecast) and https://clio.columbia.edu/catalog/15474374 (David Neelin: Climate change and climate modeling). If the links don't work for you, change browser!

There are plenty of great resources out there, and I will point to them as the class progresses. Here are some favorite:

General Public:
https://www.nature.com/scitable/knowledge/library/the-global-climate-system-74649049/
https://www.metoffice.gov.uk/weather/learn-about/weather/atmosphere/global-circulation-patterns
https://www.carbonbrief.org/qa-how-do-climate-models-work/
https://www.climate.gov/news-features/understanding-climate/el-ni%C3%B1o-and-la-ni%C3%B1a-frequently-asked-questions

Advanced topics:
https://www.meted.ucar.edu/education_training/ucourses
https://www.sciencedirect.com/referencework/9780122270901/encyclopedia-of-atmospheric-sciences
https://www.sciencedirect.com/referencework/9780123744739/encyclopedia-of-ocean-sciences
https://glossary.ametsoc.org/

Attendance Policy

Attendance of lectures is strongly encouraged. Complementary material, in addition to required readings, will be presented in lectures and included in examinations/discussions. The in-class group exercises will make up 10% of your grade.

Method of Evaluation

Grades will be based on the following:
10% for participation
60% for lab assignments
30% for final exam
1. Participation: Participation will be determined by the submission of in-class group work.
2. Lab exercises will involve hands-on/minds-on exercises with reports due at the end of each week.
3. The final exam is scheduled at the end of the course and will comprise short answers and multiple-choice questions.

Assignment Submission

All assignments will be submitted through the class website. See the Assignment_Submission_Instructions.pdf document within the “Files” section of the course website.

Late Policy

Labs are due at midnight on the Friday following each Tuesday laboratory session. Five percent (5%) of the total possible points will be deducted per day if the lab reports are submitted past the due date, up to 25% (at which point a perfect lab report will be graded 75%). Materials that are submitted more than one week late will not be accepted, barring extenuating circumstances. If you will be struggling to make a deadline, ask for help as much in advance as possible.