Last Updated: January 10, 2024

Paleoclimate (GEOL 542/ATS 542)
MSNR 320
300-415PM Monday and Wednesday

Instructors

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Scott Denning, Department of Atmospheric Sciences

Course Title: Paleoclimate
Credits: 3

Course Description: A survey of past climate and Earth system states, from the Archean to the Holocene. Special emphasis on extreme climates (pre-oxygenated atmosphere, Snowball Earth, and super greenhouse climates) and on time periods where there remains substantial model-data disagreement (early Eocene, Heinrich events). Role of paleoclimate in understanding future warming and evolution of the Earth system. Detailed look at paleoclimate proxies and their limitations. Local field trip will be offered.

Prerequisites:
CHEM 113: General Chemistry II
GEOL 154: Historical and Analytical Geology
or Consent of the Instructor

Course Content Learning Objectives:
By the end of this course, successful students will be able to:

1) Articulate the outstanding questions in paleoclimate
2) Explain the similarities and differences between past climatic change and current, anthropogenically-driven climatic change
3) Demonstrate how to reconstruct past climate from proxies and the inherent uncertainties in these proxy records
4) Detail the range of models available to reconstruct past climates at different temporal scales
5) Link climate with long-term biogeochemical cycles on Earth

Specific Course Topics/Weekly Schedule
(Week: Topic)
1: Survey of Earth History and Introduction to Paleoclimate
    Jan. 17: Value of Paleoclimate (Jeremy)

2: Climate Basics
- Jan. 22: Energy balance (Scott)
- Jan. 24: Basics of Circulation (Scott)
- Paper: Wunsch 2010 or Tierney 2020
- Assignment: The Geologic Timescale

3: Climate Basics and Forcings
- Jan. 29: The hydrological cycle (Scott)
- Jan. 31: Geologic forcings on climate and the carbon cycle (Jeremy + Scott)

4: Climate Proxies
- Feb. 5: Marine Proxies (Jeremy)
- Feb. 7: Terrestrial Proxies (Jeremy)

5: Climate Proxies (continued)
- Feb. 12: CO2 and atmospheric composition proxies (Jeremy)
- Feb. 14: Paper Discussion—CO2 Compilation (students lead)

6: Assigning Ages to Rocks—Geochronology
- Feb. 19: Astrochronology and geochronology (Jeremy)
- Feb. 21: Paper Discussion—Schoene et al. (2015) and Hull et al. (2020) (students lead)
- Assignment: First self-evaluation

7: Modeling of Paleoclimates
- Feb. 26: How GCMs work (Scott)
- Feb. 28: Boundary Conditions and Data-model comparisons (Jeremy + Scott)
- Assignment: Project Proposal
- Assignment: Virtually attend CESM Paleoclimate Working Group meeting (Feb. 26)

8: Snowball Earth and Low-Oxygen Atmospheres
- Mar. 4: Origins of Earth and the early Earth atmosphere (Scott)
- Mar. 6: Snowball Earth and the Paleozoic (Jeremy)

SPRING BREAK

9: Greenhouse and Equable Climates
- Mar. 18: Greenhouse climate episodes (Jeremy)
- Mar. 20: El Niño and oceanic responses to CO_2 (Jeremy + Scott)

10: Drivers of Long-term climate change
- Mar. 25: Paper Discussion of El Niño paper (Wara et al. 2005/Zhang et al. 2014/Tierney et al. 2019) (students lead)
- Mar. 27: Long-term climate change (Jeremy)
- Assignment: Second self-evaluation

11. The Cenozoic

Apr. 1: Hyperthermals (Jeremy)
Apr. 3: Descent into the icehouse (Jeremy)

12. Glaciations, ice-sheets, and coupled model components

Apr. 8: Paper Discussion of Gasson et al. 2016 and DeConto and Pollard 2016 (students lead)
Apr. 10: Plio-Pleistocene and the 40 ka to 100 ka orbital switch (Jeremy)
Assignment: mid-project evaluation

13: Glaciations and review

Apr. 15: The deglaciation (Jeremy)
Apr. 17: Paper Discussion of Timmermann papers (students lead)

14: Paleo-hydrology

Apr. 22: Constraining the past water cycle (Jeremy + Scott)
Apr. 24: Discussion of Feng et al. 2022 (students lead)

15: Extinctions, vegetation, and biodiversity

Apr. 29: Rise of life and plant feedbacks (Jeremy + Scott)
May 1: Mass extinctions and climate (Jeremy)

15: Project Presentations

May 6: Final Presentations

Field Trip

To learn how to study rocks and make an informed climatic interpretation from outcrop, we will do one day-long non-mandatory field trip on a weekend. This field trip will be to a nearby location. It will be an opportunity to translate what we've learned in the class into actual observations.

The timing of the field trip will be April or early May, dependent upon the weather and dependent upon availability to maximize participation. We encourage everyone to join for a fun day of discussing science in the field and to practice your own paleoclimate interpretations!

Paper Discussions

An integral part of this class will be reading foundational and cutting-edge papers in paleoclimate and discussing these papers as a class. Students will lead the discussion. Besides simply taking a deeper-dive into a particular topic, a central goal of this activity will be to learn to read papers that either discuss climate or geology and develop the confidence necessary to evaluate and use these papers. A secondary goal will be learning to harness our collective expertise to address paleoclimate questions.

For the paper discussions, students should prepare a short (max 10 minutes!) presentation about the paper, describing the motivation, methods, key findings, and ending with (provocative) questions about the paper and its conclusions. The goal of this presentation is to get everyone's mind in gear to think about the paper in a critical manner and to discuss and debate the conclusions (and also ask any questions…no question is too stupid!). The outcome should be that everyone understands the key findings, but also the critical limitations of the study and where further work might help to further our understanding of paleoclimate.

Project

The centerpiece product for this course is project where you will work approximately in groups of 4 to develop a research question, find and analyze appropriate proxy and/or climate data, and present the results to the class. We encourage you to pursue a project that overlaps with your research, will provide greater insight into your current research, or simply permits you to pursue a topic which fascinates you, but for which you have not had the necessary time to examine in detail.

The goals of this project are to learn to:

a) Develop a testable hypothesis using paleoclimate data
b) Analyze climate/paleoclimate model data
c) Find and examine paleoclimate proxy data
d) Place your findings in the context of Earth history
e) Present paleoclimate results using the appropriate geological terminology

The project will include 2 intermediary assignments: (1) an approximately 1-page project proposal where you will lay out the hypothesis and tentative methods with which you will answer this hypothesis; and (2) a late middle semester check-in and group evaluation. In both cases, Scott and/or I will provide feedback and guidance. The final assignment will center around a 15-minute presentation and discussion of your project.

Grading

During the course, there will be no numerical grades given. Numerical grades will only be assigned due to university requirements at the end of the course. Instead, this course will roughly follow the concept of "ungrading". As such, you will be asked to self-evaluate your learning through a series of short responses and discussions with Scott and me.

Beyond the course content learning objectives (see above), we aim for you will develop skills that will make you a more informed and critical scientist. These skills include:

1) Critically reading papers to pick out the primary points, identify assumptions, and formulate new questions
2) Present ideas (yours and those published previously) to your peers
3) Solicit and digest critical feedback on your ideas from your peers
4) Participate in scientific discussion, even if this participation is limited to asking clarifying questions.

The three evaluations you will submit during the semester will include self-evaluations of what you have learned and what you do not yet understand as well as self-reflections on these points above.