EPS 244: Atmospheric Evolution and Habitability of Terrestrial Planets

Spring Semester 2023

Instructor: Robin Wordsworth (rwordsworth@seas.harvard.edu), 451 Geological Museum

Location: MCZ 429 (Room 429 in the HUCE space)

Course Website: https://canvas.harvard.edu/courses/117554/

Motivation

Earth is our best-studied example of a rocky or 'terrestrial-type' planet, but many mysteries remain regarding its long-term evolution and uniqueness in the Universe. Of particular interest is the extent to which Earth's climate and biosphere have interacted and influenced each other over geologic time. Our understanding of Earth's evolution and habitability is deepened by knowledge of the other rocky planets in the solar system, such as Venus and Mars, as well as more distant objects in the outer solar system. Even further afield, the emerging science of terrestrial exoplanets will greatly enrich our understanding of planetary evolution and habitability in the near future. The aim of this course is to provide a wide overview of the state of the art of this subject, with a focus on in-class discussion of the primary literature.

Learning outcomes

You'll gain the background knowledge required to begin research on a wide range of atmospheric and planetary science topics. You will gain an understanding of the complexity of Earth and other terrestrial-type planets and the observational, theoretical and experimental techniques used to study them. Through in-class discussion and the final project, you will learn to critically evaluate the primary literature and gain new knowledge and technical skills relevant to your own research.

Requirements and resources

We'll assume a quantitative science background equivalent to that gained in a physics, chemistry or biology undergraduate degree. Other than that, there are no particular requirements. Planetary science is an incredibly diverse subject, and the aim of this course is to allow students from varied backgrounds to engage in this field without the assumption of extensive previous knowledge. This is primarily a graduate class, although upper-level undergraduates will be allowed to enrol with permission from the instructor. There is no required textbook. We will use Canvas, Google Docs and Perusall to organise classes and for online paper discussion.

Course Schedule

The course is divided into four modules. While this is primarily a seminar course focused on in-class discussion, each module will begin with an introductory lecture to summarize the main themes.

1. **Introduction:** Introduction to the course aims, overview and example paper presentation.
2. **Formation, Delivery and Loss**: Planet formation, atmospheric escape, atmospheric delivery, effect of large impactors on early atmospheres.

3. **Condensation, Climate and Chemistry**: Analysis of the factors that govern long-term climate evolution, including ice-albedo and runaway greenhouse feedbacks, atmosphere-interior interactions, and carbonate-silicate weathering.
4. **Biosphere-Climate Interactions**: Interactions between the biosphere and the climate and atmosphere, with a focus on understanding Earth history from the Hadean to the Phanerozoic.
5. **Expanding the Parameter Space**: Case studies of other planets and moons in the solar system, including Mars, Titan and Venus. Terrestrial exoplanet observational techniques and findings. Biosignature definitions and the hunt for life around other stars.

Note that this schedule may be subject to change. Any significant alterations will be noted on Canvas.

Assessment

- **Participation** (60 % of final grade). Class participation is a major part of the assessment for this course. Participation is evaluated via online discussion of papers before class, presenting papers and engaging in in-depth discussion in class, and providing feedback on other students' presentations. Class absences are permitted automatically for medical reasons or religious holidays. In other cases, prior permission from the instructor is required.
- **Final project** (40 % of final grade). For the final project, you will undertake a research assignment on a topic of your choice. Final projects may be completed individually or in groups of up to three and can be on anything related to the theme of the course. Short presentations on the final projects will be presented during the last week of class. Final project written reports will be due in exam period.

Course Policies

All lessons will take place in person, with remote attendance allowed only when no alternative is possible (e.g. for medical reasons). In all submitted work, you must always acknowledge the source of any information you use, including discussions with other students, and use of any online resources or tools. We aim to maintain a respectful and inclusive atmosphere in the class that values diverse perspectives and identities. Any suggestions on how we can improve on this are always welcome.