EOS 266: *Evolution of the Earth system*

Julia Horne

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1 Syllabus

1.1 The Basics

Instructor Julia Horne (she/her)	Location ELL 162
Office BWC A316	Class Times **Monday and Thursday** **11:30 am - 12:50 pm PDT**
Contact **juliahorne@uvic.ca**	Office Hours Wednesdays 2-3 pm (email for appointments outside of this time period)
First Class Sept. 2nd	Final Class Dec. 7th

1.2 Territory Acknowledgement

I acknowledge and respect the ləkʷəŋən *peoples on whose traditional territory the university stands and the* Songhees, Esquimalt *and* W̱SÁNEĆ *peoples whose historical relationships with the land continue to this day.*

1.3 Course Description and Context

This course is designed to illustrate the complex and inherently interdisciplinary nature of Earth systems science. Our main focus will be on understanding dynamic systems, feedbacks, and garnering a wholistic appreciation for the evolution of our planet and its climate. To this end, we will study the atmosphere, biosphere, and solid Earth (geosphere) as intertwined components of a single system: the Earth system.

1.3.1 Major Themes

We will study the evolution of the Earth through geologic time via the biogeochemical, geological, and physical processes operating on and within it. We will begin with the fundamental tools by which we study the Earth system: physical climate controls, biogeochemical feedbacks, and the exchange of mass and energy through the system. Starting with a narrow focus on Earth, we will also learn how other planetary systems will be controlled by the same forces and feedbacks (especially looking at Mars and Venus). A major focus will be the carbon cycle, which is closely linked with climate; how the carbon system has changed over time (and reflected climate variations) and the important role that life has played in its evolution. We will also investigate the geologic record for evidence of past climates and major extinction events, and evaluate the how the Earth system has arrived at its present state. In the end, we will look at modern climate and humans impacts on it (and what can be done about climate change).

1.3.2 Prerequisites

- EOS 120

- CHEM 101 or 150

For students *without* the proper prerequisite courses, you need the permission of both the course instructor (me) and the department (SEOS, in this case) to enroll. I assume that all students registered for this course have met these requirements to gain access to the Brightspace page, but some people fall through the cracks. If you are one of those individuals, you remain in this course at your own risk!

1.3.3 Pairs well with

You may want to consider the following courses for continuing study:

- EOS 225 (Earth Systems Modelling)
- EOS 261 (The Ocean-Climate System)
- EOS 321 (Earth History)
- EOS 460 (Earth System Science)

1.3.4 Official goals for students (Intended Learning Outcomes)

1. *Contextualize* major events in Earth's history; what precipitated the event, and what were the repercussions for the Earth system?
2. *Explain* the processes and feedbacks operating on Earth and how the biological, geological, and climatological systems on this planet interconnect and react to these feedbacks.
3. *Conceptualize* the complex theories of dynamical systems and chaos in the Earth system context; how do these broad theoretical frameworks apply to the Earth, and where can we see their fingerprints?
4. *Describe* systems operating at steady state and the evidence of perturbations in the geologic record; major events occurring billions of years ago left their marks on the Earth, so how do we identify this evidence and interpret the record?

1.3.5 Unofficial goals for students (Unintended Learning Outcomes)

1. *Appreciate* the complexity of the Earth system, its place in the known universe, and the amazing concepts of deep time! Arrive at a deeper understanding of our relative place in an immense timeline of events.
2. *Encourage interest* in studying Earth history, geology, and planetary evolution! My goal is to have every one of you become excited by the Earth and its mysterious ways (and hopefully consider continuing your studies in Earth science fields).
3. *Garner* a broadened, creative perspective in addressing anthropogenic climate change and foster hope and resilience in the face of this challenge! I want all of you to emerge as steadfast stewards of our glorious planet.
4. *Success in all areas!* I want all of you to come out of this class having learned something new, inspired to care for our planet, and hungry to find out more about Earth and planetary systems.

1.4 Format and Components

I have designed this class to be a hybrid of several different teaching formats: traditional lectures, round-table discussions, and online tutorials. Everyone learns differently, and 13 weeks of lecturing gets stale (for me and you) very quickly; recognizing these truths, I want to present the opportunity for each one of you to learn and engage with Earth systems science in a new way. This course will likely present some learning formats that you very much prefer, and some that you don't like very much at all; I encourage you to give me feedback (section 1.4.5) about what works for you and what doesn't and let me know why!

1.4.1 Basic weekly structure

1. **Lectures**
   Held during the Monday class periods. These will usually consist of your typical slides and me talking for an hour, but I will also leave room for discussion and lots of questions. We will likely address the biggest of these questions during our. . .

2. **Round-table discussions**
   These will take place during our Thursday classes and will be very open-ended. Discussions will usually reference the immediate previous lecture topic, but this course is about interconnected systems and as such you can expect that previously covered concepts will come up again! Asking is the key to knowing, so I am going to frequently present you with big ideas that I want you to probe. I will come prepared with a handful of deeper discussion topics, and we will get to as many of them as possible during the class period. *I am here to be your guide, but not your leader*; we will go as in depth on a topic as your inquisition demands! If the discussion on one topic is particularly vibrant and long lasting, I may choose to end it prematurely to allow time for other topics; however, I will always post the discussion topics on the Brightspace discussion forums module (with some notes I take during class as a refresher on what was covered) so that the discussion may continue outside of class. Participation in discussion forums is highly encouraged, *but not mandatory*!

3. **Tutorials**
   On a few occasions, our Thursday round-table discussions will be replaced by a guided tutorial where you work on a problem set (mostly individually, but collaboration with classmates is encouraged!) in Jupyter Notebooks. I will lead the class through a quick introduction to teach you relevant scientific computing skills that you will then use to do some calculations and/or plot and evaluate datasets. I expect that most of the problem sets will be completed (or nearly done) by the end of the class period, but some will, of course, take extra time outside of class. These problem sets count towards your graded assessments (section 1.4.6), and you will have the chance to complete them outside of class and submit your finished work to the Brightspace site by the following Thursday morning, prior to our class (approximately 11 am, 1 week later).

1.4.2 Topics

We will be covering both a lot of time and a lot of space in this course; we will begin by talking about the start of the universe and end by talking about the current moment, a particularly dramatic period. And we will cover some key theoretical topics to start, as they inform the rest of the course.

1. *Dynamical systems, chaos, feedbacks, carbon/nutrient cycles, and the Planetary fuel cell*
   (These are fundamental concepts that control the Earth and all planetary systems, among other things! These will inform the rest of the course and will likely provide the basis of our more philosophical discussions.)

2. *Genesis: Planetary accretion, the Hadean eon, and the concept of deep time*
   (How the Earth, and the rest of our solar system, became a thing and how we know it; we will compare our planet to others like it and figure out some reasons why they end up in different states. Key to this idea is understanding just how old the Earth is, how people managed to figure that out, and ways that we can conceptualize this kind of massive timespan.)

3. *Archean and Proterozoic Earth: the extreme climates*
   (This will deal with an extremely long span of history when Earth became the habitable planet that we know and love. This includes how we got this wonderful oxygen we breathe, and what exactly the ramifications of that change were; it was a harsh transition!)

4. *Paleozoic and Mesozoic Earth: Life emergent*
   (Yes, dinosaurs. Among other big beasties. This topic will cover a lot of carbon isotope evidence of climate transitions, and the triumphs and tribulations of life on Earth, a continuing theme from the previous topic. Lots of things will live, and most of them will die in massive extinctions. We will figure out why!)

5. *Cenozoic Earth: Glacial cycles and the "recent" past*
   (Almost self-explanatory; we will go over the hotter climates that started this most recent eon of Earth's history, and the extremely precise climate record that we have of the last few thousand years.)

6. *Anthropogenic Earth: Humans rise and fall?*
   (Probably the most controversial topic, and the most likely to make you mad. We will go over the very solid evidence of climate change, the causes/mechanisms of it, and some ramifications that we will see in our lifetimes. We will also move forward to more hopeful topics of what we can do as a society.)

These topics are HUGE and have very philosophical implications; while this isn't a philosophy course *sensu stricto*, I hope that all of you will make space for these deeper ponderings. Recognize that we are all people from different backgrounds and with different perspectives, and we will inevitably deal with topics that bring up challenging (and often emotional) implications, and that's ok! Learning is challenging in and of itself, and we are learning about concepts that took hundreds of years become socially acceptable. You will be challenged, one way or another, by these topics!

1.4.3 Materials

This course does not follow a textbook, and you are *not* required to purchase one. Some useful sources for supplementary reading, and the main sources which I will be regularly referencing are:

The Earth System, Kump, Kasting & Crane, 2010 (Pearson)
How to Build a Habitable Planet, Langmuir & Broeker, 2012 (Princeton)

I will occasionally add recommendations for extended research to the lecture module (and I will name drop these recommended readings in the lecture/discussion as they become relevant). Any recommended readings will be added as downloadable documents to the course Brightspace page.

1.8 A quick introduction to me

I am a geologist, studying for my PhD in Planetary Science. My research involves building numerical models of planetary systems (primarily Earth, but hopefully with theoretical planets in the future!) and evaluating environmental and geochemical changes in those systems across long periods of time. I mostly focus on nitrogen and carbon cycling between the atmosphere-ocean and mantle, trying to understand how mantle geochemistry has affected the atmospheric composition, and vice versa.

Outside of my work, I enjoy hiking/backpacking, kayaking, skiing/snowboarding, taking care of my legion of houseplants, and playing the occasional video game. My favourite books (although it's hard to choose) are all by Kurt Vonnegut; Breakfast of Champions and Galapagos, in particular. I'm a big fan of science fiction in all forms (books, comic, video games, film, etc.). I'm a horror movie buff, although I generally enjoy most film (except for Rom Coms). The same goes for music- I generally like most of what I hear, apart from Country. Johnny Cash does not count as Country.

1.9 Final notes

You deserve, as a person, to learn in an environment that is not overly stressful, and I will do my best to cultivate that environment. However, there is nothing I can do about circumstances beyond this class, such as family emergencies, interpersonal strife, or whatever else the universe has in store for us.

During this semester, we should all be looking out for one another. The university has many mental health resources available to students (see the Student Resources section above), and I encourage every one of you to routinely stop to focus on your mental health as necessary. If you or one of your classmates are struggling with something (and you can always keep the details vague!) and it's affecting your studies, please let me know and I will do my best to accommodate.

2 Course Context

2.1 Course Background

EOS 266, *Evolution of the Earth System*, is a course designed for second or third year undergraduate students who are interested in attaining degrees in Earth or Environmental sciences, or Geology. The course meets twice per week for 80 minutes each, switching between lectures (typically the Monday session, introducing a new topic) and tutorials or round-table discussions (typically during the Thursday session). All sessions are held in Elliott 122 regardless of format. Full course enrolment will be maxed out at 30 individuals and requires a minimum of 12 individuals.

The course will adhere to general competencies from the discipline and university program (Geology/Earth Sciences). Students will be knowledgeable of specific periods in Earth's history and the geochemical proxies by which they are defined; they will understand and be able to explain the theories of plate tectonics, climate change (natural and anthropogenic), planetary and solar system formation, and others; the students will write a scientific literature review or produce some other capstone project using multiple sources from peer reviewed journals, properly citing their references; and students will use computational methods (in Python) to evaluate problem sets in 3-4 tutorial sessions.

2.2 Subject Matter

EOS 266 is structured around the following core concepts:

1. The Earth is a dynamic, evolving system of interconnected feedbacks
2. Geochemical proxies, in conjunction with the rock and fossil record, are key tools to understanding the history of the Earth
3. The carbon system is a key driver of the Earth's climate history

This course is split into 6 distinct units, each spanning one to two weeks of class time (except for units 3 or 4, which may span 2.5 to 3 weeks). The first two units are more theoretical and introduce the background knowledge and concepts that students will use to understand the following 4 units, which are focused on exploring different periods in Earth's evolutionary history. The units are:

1. Dynamical systems, chaos, feedbacks, carbon/nutrient cycles, and the Planetary fuel cell
2. Genesis: Planetary accretion, the Hadean eon, and the concept of deep time
3. Archean and Proterozoic Earth: extreme climates, the emergence of life and the carbon cycle, and the oxygen catastrophe
4. Paleozoic and Mesozoic Earth: Big organisms, and bigger extinctions
5. Cenozoic Earth: Glacial and Milankovitch cycles and the "recent" past
6. Anthropogenic Earth: The rise of human society and the rapid decline of the environment

2.3 Learner Characteristics

EOS 266 is theory rather than field-experience based, and thus is not strictly geared towards those pursuing a profession in geological fields (mineral exploration, environmental engineering, etc.). Those students seeking academic or research careers will likely prefer the course, as it has a "big picture" rather than skill-based focus.

Students should have the goal of expanding their background knowledge for future geology courses (if they are majoring or minoring in the discipline, this course should be part of their graduation track). Students may also want to gain some coding and research experience, and the tutorial portion of this course will introduce them to beginner-level coding and data analysis that will aid in subjects outside of geologic studies.

Students will need some background knowledge of geological sciences, such as categorization of rocks and the rock cycle. They will also need to know something about climate controls (carbon dioxide and other greenhouse gases) and the basics of inorganic chemistry. These prerequisites should be covered in most introductory (100 level) chemistry and/or geology courses. The students will not need any prior coding or scientific writing experience.

Learners in this course will be expected to participate actively in the course discussions and tutorials, and to be present and attentive during the weekly lectures. Successful learners will keep up with the monthly quizzes and tutorial assignments, as well as their term project interim deadlines for feedback. It is the expectation in this course that students collaborate without copying their fellow students' work; assignments are all open to collaboration, as long as students declare who they helped and who helped them. Students are also expected to occasionally reflect on their own work, particularly in the process of designing and completing their term project. They are also expected to use feedback on their project design from the instructor and their peers to improve their project focus and/or timeline. Finally, students are expected to ask for help and additional feedback on their own, and to regularly check in on assignment due dates and updates on the course Brightspace calendar/announcements pages.

2.4 Instructor Characteristics

I believe that effective teaching must be in a symbiotic relationship with learning. My role as instructor is to introduce students to new ideas and methods of learning, and I am constantly modifying the format of course assignments in response to student feedback. I believe that a good gauge of learning progress is to challenge a student to teach something to the class, so presentations and research projects are emphasized in my course designs.

I have an obvious and (I hope) infectious enthusiasm for geology and Earth science. I view lower-level university courses as a unique opportunity to draw otherwise uninterested students into a subject, so in my delivery of this course I aim to engage students in a way that makes them feel excited, or at least not bored, by the many nuances and vagaries of Earth history. At the same time, there is so much to cover in this area that it can be difficult to pace the course according to the unique needs of each student cohort. I try to revisit my lecture materials each week to ensure that I am reviewing the information that they find particularly challenging, and not hyper-focusing on the information that they find more approachable.

I expect students to show engagement in the course by active participation in discussions, tutorial assignments, and projects (group or individual). I expect students to ask and respond to questions; if I find a particular student is not participating regularly in class, I will set up a meeting with them to address any issues they might be facing with the material or method of delivery. I expect high quality work from my students, but I also expect that they, as early undergraduates, will not have all the skills required to produce high quality work in all types of assignments. Thus, I expect students to ask for feedback and to use my feedback to improve their work (for instance, early in the semester they will choose a capstone project topic, with multiple opportunities to meet with me to get guidance on their progress throughout the semester).

References

Ambrose, S. A. et al. (2010). *How Learning Works: Seven Research-Based Principles for Smart Teaching*. John Wiley & Sons.

Boothe, K. A. et al. (2018). "Applying the Principles of Universal Design for Learning (UDL) in the College Classroom." In: *Journal of Special Education Apprenticeship* 7.3, n3.

Kandlbinder, P. (2014). "Constructive Alignment in University Teaching". In: *HERDSA News* 36.3, pp. 5–6.

Wiggins, G., G. P. Wiggins, and J. McTighe (2005). *Understanding by Design*. Ascd.