Syllabus for SIO 224 Internal Constitution of the Earth (Winter 2021)

<u>Instructors:</u> Professor Dave Stegman, Gabi Laske, (office hours by zoom appt via slack)

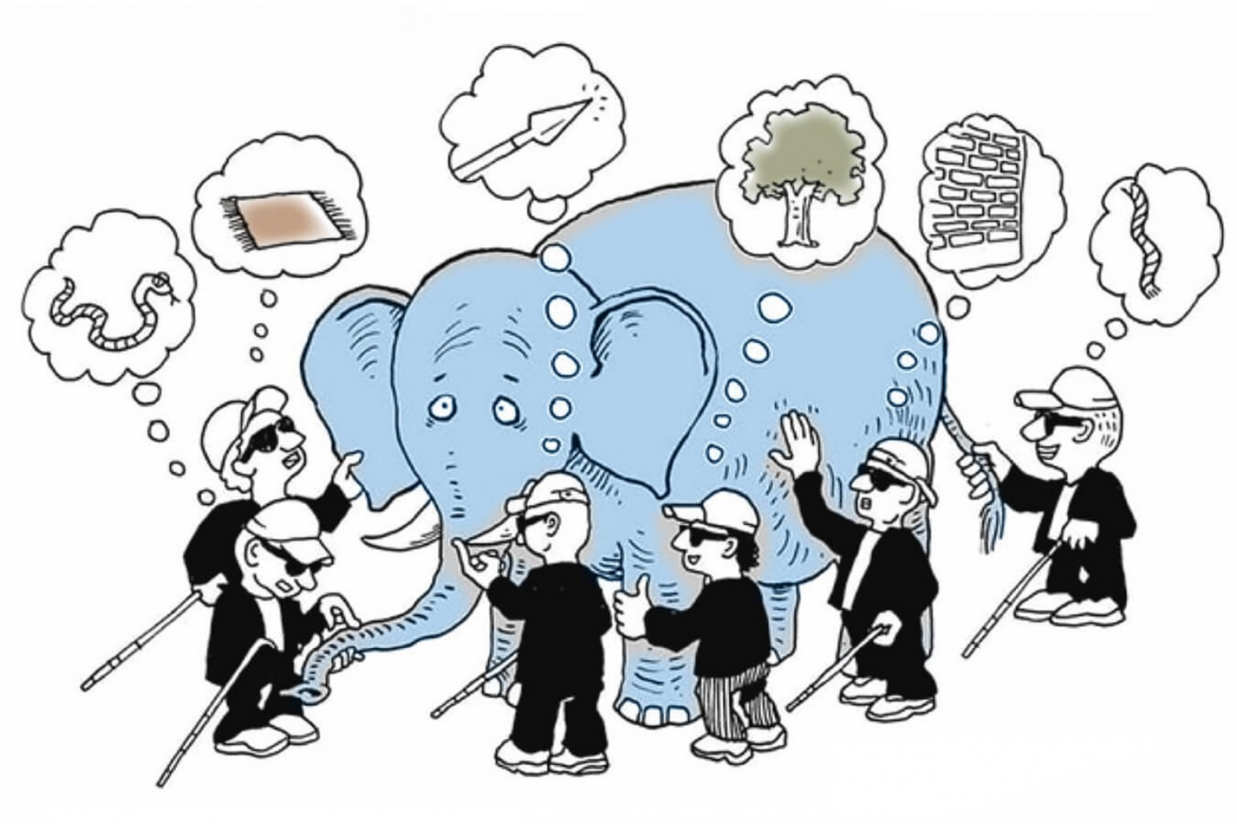
<u>Lectures:</u> Tu/Th 10:30-11:50a (remote)

80 min each: 20-30 min discussion/5 min/45-55 min classical lecture;

Discussion and Classical lectures will be recorded/posted via Zoom/Canvas

<u>Overview:</u>

The study of the structure, composition, and dynamics of Earth's interior is important and fundamental to our understanding of Earth's evolution. It is an active area of research with several major outstanding questions, and it is inherently interdisciplinary and science is not done by a 'lone genius'. Although the deep Earth is the context in this course, in general scientists need training and experience crossing these traditional boundaries to answer fundamental questions make scientific discoveries. This course provides students an opportunity to begin learning how to how to assimilate and apply knowledge from several subdisciplines in geophysics including mantle geochemistry and cosmochemistry, global seismology, thermodynamics, mineral physics, rheology, geodynamics, and geomagnetism.



It is expected that some of the material will have already been introduced in core geophysics classes such as SIO 225, 227A, 229, and 234, and this material will be reinforced.

The course materials will be on Slack (You will be sent an invite). This is a collaboration platform that is used for research, and it's a tool that you may also find useful for that, again reinforcing how science is collaborative.

There are two channels for the course: #**sio224-2021-course-materials** is going to be used for hosting teaching materials so you can access longer than the1-quarter duration allowed by canvas. Only instructors should post to this channel

The other channel is #**sio224-2021-general** and we'll use this for any questions, discussions, or other items related to the course.

<u>Content convered in this course:</u>
Here is an approximate list of the topics and order they will be covered.

0. Geochemical Earth models (week 1- Dave)

0.1 What is Earth made of? How was Earth made? How do we know?

0.2 What is the nature of Earth's heat and how is it distributed? What is the Urey number?

1. 1D Earth models (week 2- Gabi)

1.1 Reference Earth model PREM and others: historical context. How are the constructed? What data contributed? Where are discontinuities? What are their constraints?

1.2 Major discontinuities and relationship to mineral phase transformations.

1.3 Pressure with depth; compare to surface pressure; GPa vs mbar; density

1.5 Seismic Anisotropy (radial anisotropy): why is this needed in a 1D Earth model?

2. Plate tectonics (week 3- Gabi, Dave)

2.1 Basic jargon – continental drift, seafloor spreading, MORs, subduction zones, cratons, mantle plumes, hotspots, LIPs, guyots, apparent polar wander curves

2.2 Historical context of plate tectonics

2.3 The principal driving forces of plate tectonics

3. Seismic 3D models (weeks 4-5: Gabi)

3.1 construction of models: What data contributed? What methods are used? Basic features in the models. Vp vs Vs models. Some history.

3.2 Model Uncertainties. Pitfalls. Model robustness. Comparison of models (the likes of Becker et al.; cluster analysis)

3.3 interpretations of seismic models: relationship of seismic velocities with 'features' in crust and mantle; LLSVPs revisited, ULVZs

3.4 the relationship between Vp and Vs models revisited. The purpose of a Vc (bulk sound speed) model

3.5 seismic anisotropy and mantle flow

3.6 structure and rotation of the inner core

4. Rheology of the Earth (week 6: Dave)

4.1 Deformation and weakening mechanisms, flow rule

4.2 Radial viscosity structure of the Earth, dynamic geoid, slab model, Graveyard of slabs

5. Heat Transfer in the Earth (weeks 7-8: Dave)

5.1 Temperature in the deep mantle, adiabats, melting curves, experimental results. What are the constraints and uncertainties? Introduction to mineral physics

5.2 Adams Williamson equation: Where is it valid? Other Eqns of state

5.3 Introduction to Mantle Convection, governing equations, effects of heating mode, geometry, temp- and pressure dependent viscosity, convective and tectonic regimes

5.4 Dynamics of mantle plumes, Thermochemical convection, LLSVPs

5.5 Controversies about mantle plumes, their origins, constraints from geochemistry (guest lecture by Tim Jones)

6. Thermal evolution of the Earth (week 10: Dave)

6.1 Boundary Layer Theory; Thermal history models of the Earth

6.2 Geomagnetism: Age of the B-Field; Energetics of the core

<u>Assessments that will be part of this course:</u>

Homeworks will be assigned to develop problem solving, practice solving PDEs, and doing projects that reinforce the concepts of the course.

Homeworks will be turned in on Canvas.

A term paper will be assigned with the topic of mantle plumes, and each student will select a different plume of their choosing (Hawaii is not allowed). Part of the process is for us to help you decide on one based upon which aspects they are interested in. More info on this in the term paper assignment.

<u>Grading:</u>
10% Class participation (attendance, preparedness, engagement)
60% Homeworks (includes a few mini-projects)
30% Term Paper (5% of which is constructive critique of peer's draft)

Principal learning goals (draft):

Topic 0.

- recognize principal features in a geochemical Earth model
- distinguish between sources and sinks of heat and their uncertainties
- learn physical principles consistent with geochemical reservoirs
- establish principal connection to thermal evolution

Topic 1.

- recognize principal features in a 1D seismic Earth model
- distinguish between reference model and terrestrial monopole
- learn physical principles consistent with seismic models
- establish principal connection to mineral physics

Topic 2.

- get familiarized with jargon of plate tectonics
- identify observations that support plate tectonics
- recognize principal mechanisms of plate tectonics

Topic 3.

- recognize principal features in a 3D seismic Earth model
- establish relationship of observed anomalies with dynamic Earth
- recognize robustness of features of seismic imaging
- recognize pitfalls of seismic imaging and implications for dynamic Earth