GEOL/ESS 2000: Geochemical Cycles and the Earth System
Syllabus, Fall 2018

This course introduces the Earth system, bringing together elements of the solid Earth, hydrosphere, biosphere and atmosphere to achieve a more integrated view of the Earth’s major interacting parts – in other words, the Earth as a system. First, we explore the origins of the elements, the solar system, and the Earth. We then cover systems concepts in the context of Earth science. We examine the interactions between the components of the Earth system, along with their major past changes, recognizing that rocks provide a record of past conditions and are key to understanding how the Earth system works over the long term. This helps us understand where our resources come from and the effects of utilizing them. Understanding the Earth system helps us understand today’s global issues such as resource availability (water, food, materials, and energy), global climate change, and changing biodiversity. An understanding of Earth’s past changes helps us understand Earth’s present – and future - changes.

Instructor:
Dr. Carol Frost, ESB 3044, frost@uwyo.edu Office hours: Mon. 2:00-2:50, Thur. 9:00-10:50, other times by appointment.

TAs:
Fabio Da Prat, ESB 2002, fdaprat@uwyo.edu Office hours: Tues. 11-12, Wed. 12-1
Grant Copeland: ESB 1036-A, gcopelan@uwyo.edu Office hours: Mon. 1-2, Thur. 1-2

Class meeting times:
Lectures: MWF 9:00 to 9:50 Room 216 SH Knight Geology
Labs: Tues., 1:10 to 3:00 (section 10) Room ESB 1038, TA Da Prat
Tues., 3:10 to 5:00 (section 12) Room ESB 1038, TA Da Prat
Tues., 5:10-7:00 (section 11) Room ESB 1038, TA Copeland
Wed., 3:10 to 5:00 (section 13), Room ESB 1038, TA Copeland

Labs: Bring calculator and text to lab; computers will be available for the labs that need them. You can use your own laptop for some exercises. Some of the labs use software installed on the UW computers.

Required textbook: The Earth System, 3rd edition, by Kump, Kasting and Crane, Pearson Prentice-Hall, 2010. We will also post on the course website supplements covering subjects that the textbook does not cover. You are expected to read all chapters that are covered in class along with the supplements. In addition you will be assigned problems from the book, usually from the “Critical Thinking Problems” at the end of each chapter.

Prerequisites: A 4-credit 1000-level science course with lab; for geology majors this must be a 1000-level geology lab course. For ESS majors this is be a 1000-level lab course that meets ESS requirements. CHEM 1020 must be taken prior to, or concurrently with, this course.

Format: GEOL/ESS 2000 consists of 3 lectures per week, a laboratory exercise on all but the first and last weeks of class, and homework problems handed out or assigned from the book every Monday and due every Friday (in class, including exam weeks) except the first and last weeks of class. There is a “practice” problem set the first week of class that must be turned in. It will not be graded formally, but credit will be lost from the subjective evaluation as noted below if it is not turned in.
**Attendance and Note Taking:** Taking notes is an important skill. It helps your mind to go over new information, to pick the most important points from a lecture, to remember more of the content later, and to develop writing skills. You cannot take notes if you are not present in class. It is therefore expected that you come to the class and take notes on each lecture. Do not hesitate to stop us, to ask questions, to slow us down so that you have time to take in what you need to take in. If we are not stopped, we will forge ahead! We will sometimes provide materials that are not in the textbook, but whether we are working from the text or from written materials that we provide you are expected to take your own notes in whatever fashion is most useful to you. The lecture materials are available on the course website (see below), and you can print them to take notes on if you wish.

**Website:** This course will use the WyoCourses website set up for this class. The website has the syllabus, problem materials for any problems not from the book, review sheets prior to exams, lecture materials if you wish to print them out for note-taking, etc.

**Other Expectations:** Expectations in a college course are different from those that may have been the norm in some peoples’ K-12 experience. We find that in some cases people have grown used to “having their hands held” through even fairly simple problems and have come out unaccustomed to having to figure things out independently, without a step-by-step procedure provided. In this course you will have the opportunity to think your way through a problem independently. Struggle is not a bad thing – it is a way to get your brain working. Struggle teaches, and one of the more important things it teaches is self-reliance and the fact that you can do it, something that is almost impossible to teach any other way. Embrace struggle, and work through it! True independent thinking and problem solving are learned skills – and you should seize the opportunity to practice whenever possible. We are happy to answer questions – but you should grapple with each problem yourself first in order to ask the most useful questions. Forming good questions is also an important learned skill.

Other more specific expectations I have of you in this course:

1) I assume that you are here to learn and will behave accordingly.

2) I assume that you have learned basic algebra. I also assume that you know a bit about chemistry, chemical elements, what a mole is, and basic chemical equations. You will need to use these skills.

3) I assume that you have sufficient self-motivation to apply your skills to the problems, studying, and labs in this course. By this, I mean that you will (a) read what you need to read, (b) not simply read a problem and throw up your hands in frustration without trying. I expect you will take the problem as far as you can without help.

4) I assume that you are a grown-up. This is nothing like high school. What comes with this is the expectation that you will apply yourself to your studies.

5) Don’t sell yourself short. I very, very rarely encounter people who are not perfectly capable. Usually, difficulties in courses like this one come from lack of attention or lack of the needed background, not lack of brains. Wyoming taxpayers generously support the only 4-year university in the state. They do not do so to have a second-rate institution. Despite the many headwinds that universities in small places like Wyoming endure, UW is ranked among the top 400 universities in the world out of thousands. The Geology and Geophysics department Ph.D. programs have ranked as high as 12th in the nation (on a list that had Harvard at 13th). You get access to this expertise at a small fraction of the cost of places like Harvard. Take
full advantage of such opportunity. We all want and need you to succeed – and success will only come with work. There’s no secret to it.

Evaluation/Grading:
The basis for grading will be 3 in-class hour exams, a final exam, lab performance, and homework performance. In addition, there is a subjective evaluation that we call, in general terms, “professionalism”.

Hour Exams:  
- Friday Sept. 21  
- Friday Oct. 19  
- Friday Nov. 16 (all hour exams in classroom)

Final Exam:  
- Wednesday Dec. 12, 8:00 am to 10:00 am (in classroom)

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Note that content from the labs is in part meant to reinforce material introduced in class and therefore may – possibly - be included on the tests. Lab subject material is also meant sometimes to familiarize you with material not covered in class, i.e., to supplement class.

Please note there are no scheduled make-up tests. If you have to miss a test for a medical or other emergency let the instructor know prior to the test date to make alternative arrangements. Such arrangements cannot be made after the test.

Lab write-ups are due at the following lab session. Late labs will receive a 10% automatic reduction in grade. Labs more than one week late will receive no credit. If you will need to miss a lab for a very good reason, contact the TA to make prior alternate arrangements. I have asked the TAs not to do any make-up labs unless students have made appropriate prior arrangements. If you have a problem with this policy, see me, not the TAs.

Homework problems that are up to one week late will also receive a 10% reduction. Homework problems more than one week late will receive no credit.

Other Policies:
1) Cheating. University Regulation 802, revision 2, defines academic dishonesty as “an act attempted or performed which misrepresents one’s involvement in an academic task in any way, or permits another student to misrepresent the latter’s involvement in an academic task by assisting the misrepresentation.” There is a well-defined procedure to judge such cases, and serious penalties may be assessed. In this class, your exams are expected to be your work ONLY. You may work together on problems and labs, provided that the work you turn in represents your own thinking on the subject. We should point out that it is painfully obvious when a bunch of students all make the same mistakes and get the same wrong answer, even using the same symbols! We do notice this.

2) Conduct. University Regulation 29, change 1, states that the instructor can “establish reasonable standards of conduct for each class which should be made known at the outset.” In this class I expect engagement and participation, including regular attendance, and that we
all treat each other with courtesy and respect. This does not mean we have to agree with each other- but professionalism and civility are an expectation.

3) College of Arts and Sciences document, A&S - Students and Teachers Working Together. A 5-page document is available at: http://www.uwyo.edu/as/current-students/
After getting to this site, click on “Students and Teachers Working Together”
This document lays out the guidelines for the course syllabus, attendance, classroom etiquette (no sleeping or cell phone use!), phone and email protocol, office hours and how to make appointments outside of office hours. Good stuff.

4) Disabilities. If you have a physical, learning, or psychological disability and require accommodations, please let the instructor know immediately. You will need to register with, and provide documentation of your disability to University Disability Support Services (UDSS) (in “Student Educational Opportunity”), 109 Knight Hall, Phone: 307 766-6189, Fax: 307 766-4010, Email: udss@uwyo.edu

5) University non-discrimination statement. UW faculty are committed to upholding the University’s non-discrimination policy. Under Title IX, discrimination based upon sex and gender is prohibited. If you experience an incident of sex- or gender-based discrimination, the university encourages you to report it. While you may talk to a faculty member, understand that as a "Responsible Employee" of the University, the faculty member MUST report information you share about the incident to the university’s Title IX Coordinator (you may choose whether you or anyone involved is identified by name). If you would like to speak with someone confidentially, there are people who can meet with you. Assistance and resources are available, and you are not required to make a formal complaint or participate in an investigation to access them. Faculty can help direct you or you may find info about UW policy and resources at http://www.uwyo.edu/reportit

Expected Outcomes:

By the end of this course, you should be able to:

1) Explain to others the origins of the universe, the elements, the solar system, and the Earth on a sound scientific basis including an understanding of the structure of atoms, isotopes, nucleosynthesis, radioactive decay, neutron capture, and other processes.

2) Mathematically describe exponential decay as applied to radiometric dating of rocks and other materials.

3) Understand and quantitatively apply the concept of steady state in many different contexts.

4) Understand the difference between perturbations and forcings, interactions between the parts of a system, positive and negative linkages between system parts, and positive and negative feedback in systems of interacting parts.

5) Understand and construct computer models of simple systems.

6) Explain to others the Earth’s energy balance between the total input of energy to the planet from the sun and total output of energy from the planet in the form of radiation, including the application of steady state concepts to this balance (see number 3 above).

7) Explain to others how a system of interacting parts can be self-regulating, such as in the Daisyworld model.
8) Understand the major factors in atmospheric circulation on Earth, including heat and mass transport, pressure gradients, geostrophic winds, etc.

9) Understand the major factors in ocean circulation on Earth, including gyres, thermohaline circulation, convergent and divergent circulation, etc.

10) Understand the major components of the Earth’s cryosphere.

11) Explain to others the circulation of the solid Earth (plate tectonics).

12) Understand the major components of the Earth’s carbon cycle, including the difference between organic and inorganic carbon, major carbon reservoirs, and the flux of carbon between reservoirs.

13) Understand the basics of how carbon dioxide dissolves in water to create carbonic acid.

14) Understand the basics of energy flow through biological systems, including the ability to recognize photosynthesis and respiration; understand the necessities of life such as sources of carbon, of water, and of energy.

15) Understand the basics of the genomic tree of life and a few basic relationships among the different major branches of living things.

16) Understand the properties of the earliest life forms, their basic chemical requirements, and their impact on the global environment over long periods of time.

17) Understand the difference between oxidizing and reducing conditions, the oxygen cycle on Earth, and the rise of oxygen in Earth’s atmosphere due largely to biological activity.

18) Understand and explain the major outlines of Earth’s climate regulation systems.

19) Understand what is meant by basic biological terms such as taxonomy, extinction, natural selection, evolution, adaptation – and understand major events in the history of biology and biodiversity on Earth and their relationship to climate changes and major events such as asteroid impact events.

20) Understand the major outlines of Earth’s climate history, including major glaciation events.

21) Understand the Earth’s orbital parameters and their influence on solar energy input to Earth (Milankovitch cycles).

22) Understand current thinking with regard to the origins and feedbacks affecting ice ages during the last ~800,000 years of Earth’s history.

23) Understand the scientific reasoning behind climate change and global warming on Earth now and in the future, with reference to past climate events that affected people profoundly.

24) Understand how large the anthropogenic carbon, nitrogen, and other fluxes are compared to natural fluxes (flows of energy or material between reservoirs in a system).

25) Understand the limits of exponential growth and ideas concerning the carrying capacity of Earth with regard to its human and other populations.

26) Understand the basics of Laramie’s municipal water supply with regard to local geological structures.
27) Be able to solve quantitative problems with regard to exponential decay, exponential growth, steady state, the interaction of a system’s parts, atmospheric concentrations and masses, energy input and output, matter and energy fluxes, mineral formulae and their meaning, and atmospheric processes.

University Studies:

GEOL/ESS 2000 carries an “SE” designation under the older University Studies Program requirements (but does not carry a “PN” designation). As such it contains significant content addressing the Earth-Sun relationship and astronomy (in the form of thinking about where our universe, solar system, and elements came from as well as the role of Earth-sun relations in modulating Earth’s climate through Milankovitch cycles), and geological features and principles as applied to understanding the components, linkages, and feedback loops in the Earth System. We look at and interpret maps, we include large course segments that deal with the atmosphere and climate systems, we look at ocean circulation and nutrient systems, and we cover the role of soils, vegetation, and microorganisms in the Earth system.

The course goes beyond the basics of Earth science, taking a more quantitative approach than in 1000-level introductory courses. The subject is an excellent one for showing how present-day scientific thinking is the result of adjusting to new evidence as that evidence has been uncovered. The laboratory exercises and lecture content provide extensive familiarization with the scope and limitations of the scientific method, and the subject of climate in particular amply demonstrates relationships between scientific research and contemporary society. The laboratory exercises provide you with an opportunity to work with aspects of the Earth system in quantitative fashion, as well as to make measurements that allow us to derive simple quantitative relationships.
Generalized Class Outline:
NOTE: This is an approximation for information purposes. I reserve the right to change materials at any time. There are many reasons why the schedule may change, including simply the number of questions in class. This outline should therefore not be used for assignments – attend class for definitive news about assignments.

Week 1: Introduction, origin of universe, elements, solar system
   Wed. Aug. 29: Introduction, Initial Logistics
   Fri. Aug. 31: Atoms, Fundamental Forces, Atomic Decay
      Read supplementary material Broecker Ch 2 (No lab, but work on Problem 1)

Week 2: Origins continued, with radiometric dating
   Mon. Sept. 3: Labor Day Holiday, no class  
      NOTE: No labs this week!!
   Wed. Sept. 5: Radiometric Dating
   Fri. Sept. 7: Big Bang, Stars, Nucleosynthesis
      Problem 1 due
      Read supplementary material Broecker Ch 1, 2

Week 3: Systems Introduction
   Mon. Sept. 10: Origin of the solar system
   Wed. Sept. 12: Chapter 1, Global Change
   Fri. Sept. 14: Chapter 2, Systems
      Read supplementary material Broecker Ch 1-4; read Chapters 1 and 2
      Lab 1: Radiometric age dating and meteorites
      Problem 2: Exponential Decay (handout)

Week 4: Energy Balance
   Mon. Sept. 17: Chapter 3, Energy Balance
   Wed. Sept. 19: Chapter 3, Continued
   Fri. Sept. 21: Exam 1
      Read Chapter 3
      Lab 2: Rocks and Minerals Review
      Problem 3: Steady State (handout), Critical Thinking Problem #4, page 35

Week 5: Atmospheric Circulation, Ocean Circulation
   Mon. Sept. 24: Chapter 3, Continued
   Wed. Sept. 26: Chapter 4, Atmospheric Circulation
   Fri. Sept. 28: Chapter 4, Continued
      Finish Chapter 3, Read Chapter 4
      Lab 3: Daisyworld – A Systems Model in InsightMaker
      Problem 4: Radiating temperatures of terrestrial planets (handout), and Critical Thinking Problem #6, page 56

Week 6: Cryosphere, Plate Tectonics
   Mon. Oct. 1: Chapter 5, Ocean Circulation
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*  Fri. Oct. 5: Chapter 6, Cryosphere  
  Read Chapters 5 and 6  
  Lab 4: Light Intensity, Energy Balance  
  Problem 5: Relative Humidity and Dewpoint (handout) |

**Week 7: Plate Tectonics, A Review**
- Mon. Oct. 8: Chapter 7, Circulation of the Solid Earth.
- Wed. Oct. 10: Chapter 7, Continued
- Fri. Oct. 12: Chapter 8, The Carbon Cycle
  - Read Chapter 7, start 8
  - Lab 5: Thermal Steady State
  - Problem 6: Critical Thinking Problem #1, page 148 (use Excel to do this, turn in printed graph with correct profile, horizontal axis in kilometers, not time!)

**Week 8: The Carbon Cycle**
- Mon. Oct. 15: Chapter 8, Continued
- Wed. Oct. 17: Chapter 8, Continued
- Fri. Oct. 19: *Exam II*
  - Read remaining part of Chapter 8
  - Lab 6: Using InsightMaker to model thermal steady state
  - Problem 7: Critical Thinking Problem #4, page 174

**Week 9: The Biosphere**
- Mon. Oct. 22: Chapter 9, The Biosphere
- Wed. Oct. 24: Chapter 9, Continued
- Fri. Oct. 26: Chapter 10, Early Life
  - Read Chapters 9, 10
  - Lab 7: Thermohaline circulation and water density
  - Problem 8: Rainwater pH (handout)

**Week 10: The Effects of Life on Earth**
- Mon. Oct. 29: Chapter 11, Effect of Life on Earth
- Wed. Oct. 31: Chapter 11, Continued
- Fri. Nov. 2: Chapter 12, Long-Term Climate Regulation
  - Read Chapters 11, 12
  - Lab. 8: Weathering
  - Problem 9: #1, Critical Thinking Problems, page 174

**Week 11: Climate Regulation**
- Mon. Nov. 5: Chapter 12, Continued
- Wed. Nov. 7: Chapter 13, Biodiversity Through Earth History
- Fri. Nov. 9: Chapter 13, Continued
  - Read Chapter 13
  - Lab. 9: Carbon Cycle
  - Problem 10: #1, Critical Thinking Problems, page 232
Week 12: Biodiversity
Mon. Nov. 12: Chapter 14, Pleistocene Glaciations
Wed. Nov. 14: Chapter 14, Continued
Fri. Nov. 16: **Exam III**
   Read up through Chapter 14
   Lab 10: Life lab
   Problem 11: #1, Critical Thinking Problems, page 253 (all parts!)

Week 13: Glaciations
Mon. Nov. 19: Chapter 14, continued
Wed. Nov. 21: Thanksgiving Break, NO CLASS
Fri. Nov. 23: Thanksgiving Break, NO CLASS

Week 14: Global Change
Mon. Nov. 26: Chapter 15, Global Warming Part I
Wed. Nov. 28: Chapter 15 continued
Fri. Nov. 30: Chapter 16, Global Warming Part II
   Read Chapter 15, 16
   Lab. 11: Exponential Growth
   Problem 12: Critical Thinking Problem #2, page 271

Week 15: Where are we headed?
Mon. Dec. 3: Chapter 16, continued
Wed. Dec. 5: Chapter 18, modern extinction
Friday. Dec. 7: Chapter 18, modern extinction
   Read Chapter 16, 18 and supplementary material
   Lab 12: Laramie’s water supply
   Problem 13: Critical Thinking Problem #3, page 319

“Week” 16: Wrap-up
Mon. Dec. 10: Wrap up

Final Exam: Wednesday, Dec. 12, 8-10 am, in the classroom (GE 216)