

“Atmosphere-Ocean dynamics and Implications for future climate change”

Syllabus

ENVS 312/PHYS 312, Spring 2013

CHEM 119. Mo: 10am-11am and Tu: 2pm-5pm

Instructor: Dr. Irina Marinov (research specialty: oceanography, climate modeling, carbon cycle)

This course covers the fundamentals of atmosphere and ocean dynamics, and aims to put these in the context of climate change in the 21st century. The lectures will focus on the physical mechanisms responsible for the global energy balance and large-scale atmospheric and oceanic circulation. We will introduce fundamental concepts of fluid dynamics and we will apply these to the vertical and horizontal motions in the atmosphere and ocean. Fundamental concepts covered include: hydrostatic law, buoyancy and convection, basic equations of fluid motions, flow on a rotating planet, Hadley and Ferrel cells in the atmosphere, Walker circulation, thermohaline circulation, modes of climate variability (El-Nino, North Atlantic Oscillation, Southern Annular Mode), wind driven ocean circulation, turbulent flow.

Aimed at undergraduate and graduate students who have no prior knowledge of meteorology or oceanography or training in fluid mechanics. This is a general course, which spans many sub-disciplines: fluid mechanics, atmospheric science, oceanography, hydrology. The course will include sessions in which students will learn how to write and run simple Matlab programs to study the climate system. Computer related assignments will enhance the learning of the class material. No prior Matlab experience is needed.

Prerequisites: Math 114 or instructor permission

General Goals:

- For you to learn basic atmosphere and ocean dynamics, in order to be able to understand fundamental climatic processes and future changes.
- To deepen your insights into methods of scientific inquiry. To improve your math and scientific skills, teach you basic modeling in MATLAB, a very useful computing language with a great visual interface and a solid online help manual.
- To give you a sense of the incompleteness of our understanding of the climate system and acquaint you with major areas of inquiry, which you might want to pursue later.
- *To get you excited about the field of climate science. More researchers are needed in this field. Great graduate school and job opportunities out there waiting for you!*

Instructor: Dr. Irina Marinov, Office: Hayden Hall 254B. (imarinov@sas.upenn.edu) Webpage: <https://climate.sas.upenn.edu/>

Class meeting days/time and classroom assignment:

Mon 10am-11am, Tuesday 2pm-5pm, CHEM 119. Labs will meet in the DRL computer lab.

Office Hours: Mondays 11am-noon, Hayden 254B. Alternatively, email me with times that work for you, or call me to see if I am in.

Readings:

Main textbook (on reserve and 10 copies at the Penn Book Center at 34th and Walnut)

- "Atmosphere, Ocean and Climate Dynamics: An Introductory Text" by John Marshall and Alan Plumb, Academic Press 2008.

Additional books (Rosengarten Reserve, Van Pelt library):

- “Global Physical Climatology” by Dennis Hartmann, Academic Press, 1994. I particularly like chapters 1-5.
- “Ocean Dynamics and the Carbon Cycle, principles and mechanisms”, R.G. Williams and M.J. Follows, Cambridge Univ. Press 2011.
- “Introductory Dynamical Oceanography”, 2nd ed., by Pond and Pickard, Pergamon Press.
- “Physics, Principles with applications” by D. Giancoli. Prentice Hall, 2005, general introductory physics text, particularly useful if you haven’t had physics in a while or to brush up on basic concepts as needed.

Free Online access books:

- The IPCC report: “Climate Change 2007, The Physical Science Basis, and “Impacts, Adaptation and Vulnerability” at <http://www.ipcc.ch/>
- “Introduction to Physical Oceanography” by Bob Stewart, online only, free at http://oceanworld.tamu.edu/home/course_book.htm

Grading:

Modeling and data analysis labs: 35%

Midterm exam: 25%

Homeworks: 25%

Final oral presentation + class participation: 15%

Note 1: Homeworks and MATLAB Lab exercises have a lot of weight, so pay close attention to them. You are encouraged to discuss the assignments and labs with each other, but you need to do the write up individually.

Note 2: Late homeworks and labs will result in a lowering of the grade by 20% for each day late.

Extra Math sessions:

If needed (and upon request), we can schedule additional math review sessions, to cover the basic calculus and mechanics concepts needed in the class.

Academic dishonesty and plagiarism

See the student handbook or go to <http://www.vpul.upenn.edu/osl/acadint.html>. In addition, you will be required to sign your exams and your signature will be verified for authenticity.

Policy on Religious Holidays: The University recognizes/observes holidays as listed on <http://www.vpul.upenn.edu/osl/holidays.html>. If you observe any other holidays, please make special arrangements in person with me within the first two weeks of class.

Breakdown of the course in spring 2012:

This course is divided in 2 parts:

1. Atmospheric Dynamics and Equations of Motion
2. Ocean Dynamics and Climate

Part 1. Atmospheric Dynamics and the Equations of Fluid Motion:

Week 1 (Jan 17)

- Topic 1: Introduction: The greenhouse effect. Global Energy balance. A basic Math/physics review.

Week 2 (Jan 23-24)

- Topic 2: The global energy budget.
- Topic 3: The vertical structure of the atmosphere and ocean.

Week 3 (Jan 30-31) and Week 4 (Feb 6-7)

- Topic 4: Convection in the atmosphere and ocean
- Topic 5: Horizontal Motion in the Atmosphere. Coriolis force and Large-scale Dynamics of the atmosphere
- Topic 6: Continuity and Thermodynamic Equations
- Topic 7: Equations of fluid motion: Momentum Equations.
- Topic 8: Scaling the Equations of motion: dimensional analysis

Week 5 (Feb 13-14)

- **MATLAB Lab 1.** Your first simple climate models (energy balance box models)

Week 6 (Feb 20-21):

- Feb 21: **MATLAB Lab 2:** Your second simple climate model. Ice-albedo feedback and multiple steady states. Energy balance box model.
- **MATLAB Lab 3:** Paleoclimate (extra credit)

Part 2. Ocean Dynamics and Climate

Week 7 (Feb 27-28)

- Topic 9: Intro to the Oceans: T, S, density and thermohaline circulation.

- March 5-6th: Spring break

Week 8 (March 12-13) and beyond:

- Topic 10: Introduction to the carbon cycle.
- Topic 11: Modes of Climate Variability, ocean-atmosphere interaction, annular modes (El Nino, North Atlantic Oscillation, Southern Annular Mode)
- Topic 12: Tracers of ocean circulation: biological tracers, CFCs, radiocarbon, Helium, Tritium
- **MATLAB Lab 4:** How diffusion drives the temperature, salinity and radiocarbon vertical distributions in the ocean (1D advection-diffusion models with no time dependence).
- **MATLAB Lab 5** (1D advection-diffusion equation with time dependence)
- Topic 13: Wind driven ocean circulation: Ekman flow and pumping. Why are there gyres in the ocean?
- Topic 14: Wind driven ocean circulation: Sverdrup, Stommel and Western Boundary Currents: Why is there a Gulf Stream?
- **MATLAB Lab 6:** The Stommel model: simulating ocean gyres (2D advection-diffusion)
- Topic 15: Vorticity; Conservation of potential vorticity
- Topic 16: Geostrophy and thermal wind in the ocean. Sea surface height.
- Topic 17: Eddies and baroclinic instabilities in the ocean and atmosphere
- Topic 18: Summary of class. Sample research presentation on “Ocean physics and biology”
- Finals Week: April 30th-May 8th: Student oral presentations and final homework.