# Introduction to Earth System Science

## AOSC 680

Ross Salawitch: rsalawit@umd.edu

Class Web Sites:
http://www2.atmos.umd.edu/~rjs/class/fall2022
https://umd.instructure.com/courses/1327017

Photograph by NASA Astronaut Don Pettit: https://www.pinterest.com/pin/212161832415650804

## Lecture 0: Introduction & Logistics

## 30 August 2022

# Introduction to Earth System Science

## AOSC 680

Ross Salawitch: **rsalawit@umd.edu**

1) Fine to address me as “Ross” in emails

2) Please, please, pretty please: try to remember to use “AOSC 680” in *the subject* of any class related email

3) I prefer email rather than messages sent via Canvas. I will do my best to reply to messages sent either way

4) The signature line of my standard email contains my personal cell phone number; please use this “judiciously” and note I prefer text messages to voice mail

5) Office hours do not make sense in Fall 2022: please email me to setup meetings, which could occur either in person or on my personal Zoom channel (included in the signature line of my standard emails)

**6) Please note we shall meet in person until further notice and I will strive to successfully record each lecture**

# Class Website, External

https://www2.atmos.umd.edu/~rjs/class/fall2022/ 90%

Most Visited Getting Started Most Visited Getting Started Business Roundtable Server Not Found Other Bookmarks

## AOSC 680 Introduction to Earth System Science

Instructor: Ross Salawitch

Tues-Thurs, 2:00 to 3:15 pm, Atlantic 2316

Fall 2022: 3 units

**Required Texts:**

**Chemistry in Context: Applying Chemistry to Society 7th edition**
The Chemistry in Context text can be purchased, rented from me for $20 (refunded upon return of book), or downloaded here. I'll review how to open the PDF file, if downloaded, in class on 30 August 2022.

Princeton Primers in Climate:

- Atmospheres, Clouds, and Climate by David Randall
- Climate and Oceans by Geoffrey Vallis
- Climate and Ecosystems by David Schimel
- The Cryosphere by Shawn Marshall

These four Princeton Primers in Climate books, available in various formats including paperback for less than $30 each, will be the primary source for the student led discussions, which will take place from 13 Oct until 2 Dec. We will almost certainly read multiple chapters from the first three of these books, and will delve into the fourth if there is student interest in reading about the cryosphere.

Syllabus

ELMS Course Page

**http://www2.atmos.umd.edu/~rjs/class/fall2022**

**Syllabus is at:**
**https://www2.atmos.umd.edu/~rjs/class/fall2022/syllabus/AOSC680_Fall2022_Syllabus.pdf**

**Canvas Course page at:**
**https://umd.instructure.com/courses/1327017**

# Syllabus

**AOSC 680: Introduction to Earth System Science**

**Instructor**: Ross Salawitch (301-405-5396; rsalawit@umd.edu)

**Fall 2022: Tues – Thurs 2:00 to 3:15 pm, Atlantic 2316**

**Websites:** http://www.atmos.umd.edu/~rjs/class/fall2022 & https://umd.instructure.com/courses/1327017

**Required Text:**

Chemistry in Context: Applying Chemistry to Society **7th Edition** American Chemical Society
(You can either purchase, rent a used copy from me for $20 refundable upon return of the book, or use a password protected PDF file I'll provide to registered students)

Paris Climate Agreement: Beacon of Hope by Ross J. Salawitch *et al.* (available for free via open access)

Atmospheres, Clouds, and Climate by David Randall

Climate and Oceans by Geoffrey Vallis

Climate and Ecosystems by David Schimel

The Cryosphere by Shawn J. Marshall

These four Princeton Primers in Climate books, available in various formats including paperback for less than $30 each, will be the primary source for the student led discussions, which will take place from 13 Oct until 2 Dec. We will almost certainly read multiple chapters from the first three of these books, and will delve into the fourth if there is student interest in reading about the cryosphere.

**Supplemental Text** (selected readings will be provided):

Global Warming: The Complete Briefing **5th Edition** by John Houghton (selected readings will be provided)

**Course Description.** An introduction to the study of the earth as a system: atmosphere, oceans, land, cryosphere, solid earth, and humans. Cycling of materials and energy in the earth system: the energy cycle, the hydrologic cycle, the carbon cycle, the nitrogen cycle. Climate processes and variability: land-atmosphere, ocean-atmosphere, biosphere-climate, and human interactions, short- and long-term variability in climate. Thus class will be taught at a level appropriate for first year graduate students in Atmospheric and Oceanic Science.

**Prerequisites:** AOSC graduate student *OR* being advised by an AOSC Faculty Member *OR* permission of instructor.

**https://www2.atmos.umd.edu/~rjs/class/fall2022/syllabus/AOSC680_Fall2022_Syllabus.pdf**

# Syllabus

**Class Philosophy:** We'll begin in traditional format, consisting of 9 lectures designed to provide a broad background to Earth System Science. This portion of the class will make use of equations, at a level considerably simpler than you will see in the other AOSC Core Classes. We will then transition to the student led discussion part of class, which will make use of either three or perhaps all four of the most excellent Princeton Primers In Climate series. These readings, which consist of light equations, emphasize **fundamental understanding of concepts in Earth System Science**, which is the mantra of this class. Each book is available in a variety of formats, including paperback for less than $30 each.

**Grades:** Grades will be based on the problems set (10%), admission tickets (30%), one in class exam (20%), the student led presentation (20%), and the final project (10%) and final paper (10%). All students are required to write a research paper that is 6 to 8 pages long (single-spaced; length does not include figures or references) on a topic of their choosing related to the material covered in class. All students will make deliver two in class presentations: one based on a chapter or two selected from one of the required books in the Princeton Primers in Climate Series (this will be an hour long discussion) and the second based on a research project (this will be a 10 minute presentation).

**Course Topics**

- How to Build a Habitable Planet: Geological Evolution of Earth's Atmosphere
- Overview of Global Warming
- The Greenhouse Effect: Radiative Transfer; Cloud and Water Vapor Feedbacks
- Climates of the Past
- Modeling of Earth's Climate
- The Global Carbon Cycle
- Biogeochemical Cycles of Methane and Nitrous Oxide
- Selected readings from:
  - *Atmosphere, Clouds and Climate* by David Randall
  - *Climate and Oceans* by Geoffrey Vallis
  - *Climate and Ecosystems* by David Schimel
  - *The Cryosphere* by Shawn J. Marshall

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# Class Website, External

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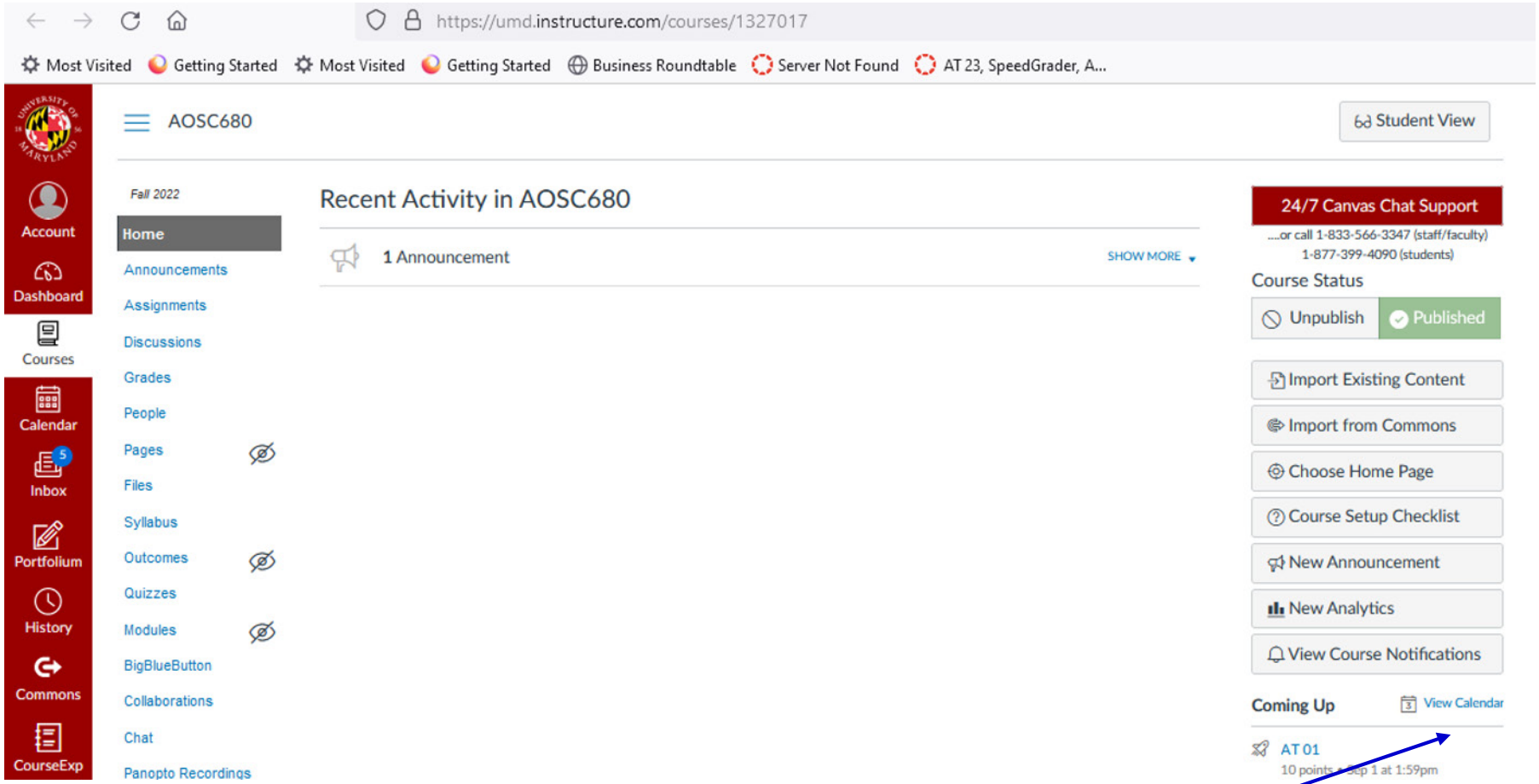
## 2. Schedule

| Date | Lecture Topic | Required Reading | Admis. Tickets | Lecture Notes | Problem Sets | Additional Readings | Learning Outcome |
|---|---|---|---|---|---|---|---|
| 08/30 | Class Overview | No reading for first meeting | No AT | Lecture 0 Video | | | No Quiz |
| 09/01 | Geological Evolution of Earth's Atmosphere | Paris Beacon of Hope Sec 1.1, 1.2 (intro), and 1.2.1 (11.5 pages) | AT 1 | Lecture 1 Video | | Ivany and Salawitch, *Geology*, 1993 NOVA: The Day The Dinosaurs Died | Quiz 1 |
| 09/06 | Overview of Global Warming | Climate Change Evidence and Causes, Royal Society (36 pages) IPCC 2007 FAQ (1.1, 1.2, 1.3, 2.1, & 3.1) (11 pages) Paris Beacon of Hope Sec 1.2.2 (3 pages) | AT 2 | Lecture 2 Video | | Kerr, *Science*, 2007* Warming Animation ENSO Video Entire IPCC 2007 FAQ | Quiz 2 |

**AT 1: Admission Ticket Number 1**
**Due prior to the start of Lecture 1 (this Thurs) based on reading for Lecture 1**
**More about ATs to soon follow**

**https://www2.atmos.umd.edu/~rjs/class/fall2022**

# Class Website, Canvas (Calendar View)




**Click here for Calendar View**

**https://umd.instructure.com/courses/1327017**

# Class Website, External

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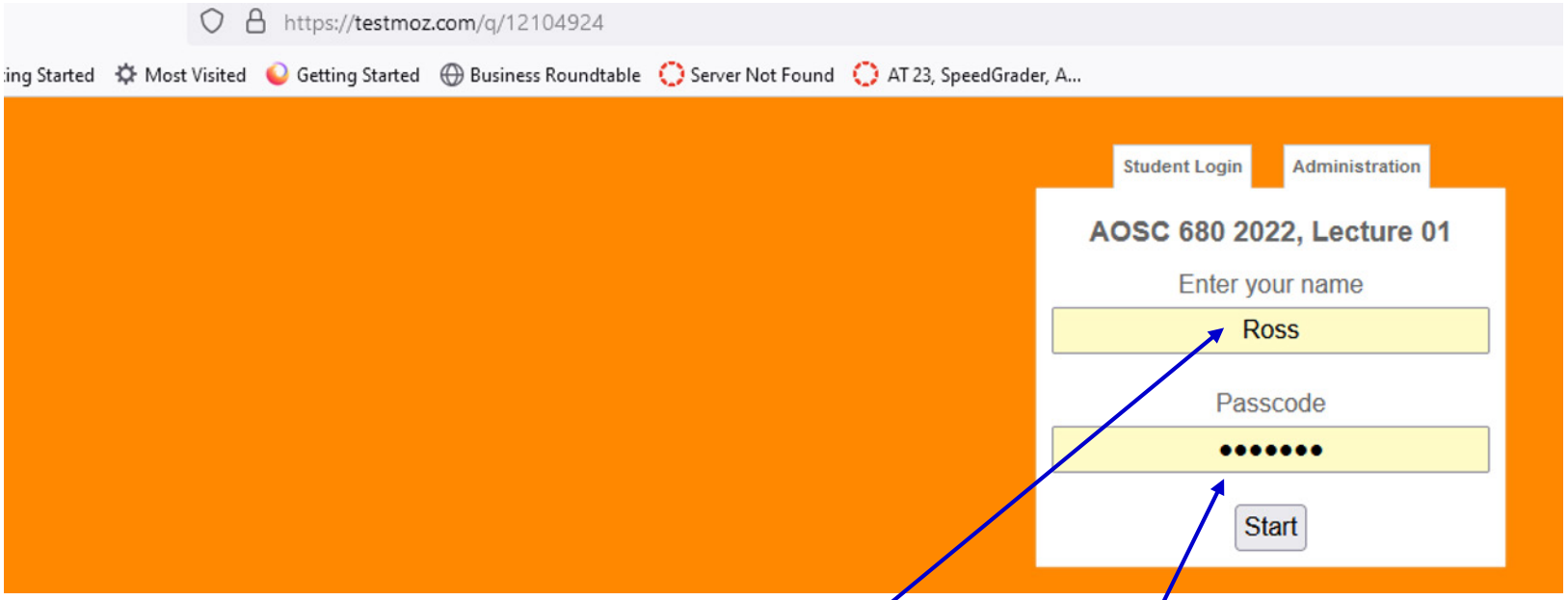
**Learning outcome Quiz: https://testmoz.com/q/12104924**
**Note: must use passcode of _____ to access**

**https://www2.atmos.umd.edu/~rjs/class/fall2022**

# Class Website, External

**Learning outcome Quiz: https://testmoz.com/q/12104924**




**Please use your real name here.**

**Must use _____ here.**

**Links to these learning outcome quizzes will be posted in the "Learning Outcome" column of https://www2.atmos.umd.edu/~rjs/class/fall2022**

# Text Books

Required Textbook: *Chemistry in Context: Applying Chemistry to Society*, American Chemical Society ⇒ **7th Edition !**

*Atmospheres, Clouds, and Climate* by David Randall
*Climate and Oceans* by Geoffrey Vallis
*Climate and Ecosystems* by David Schimel
*The Cryosphere* by Shawn Marshall

These four **Princeton Primers in Climate** books, available in various formats including paperback for less than $30 each, will be the primary source for the student led discussions, which will take place from 13 Oct until 2 Dec.

We will almost certainly read multiple chapters from the first three of these books, and will delve into the fourth if there is student interest in reading about the cryosphere.

Supplemental Texts:

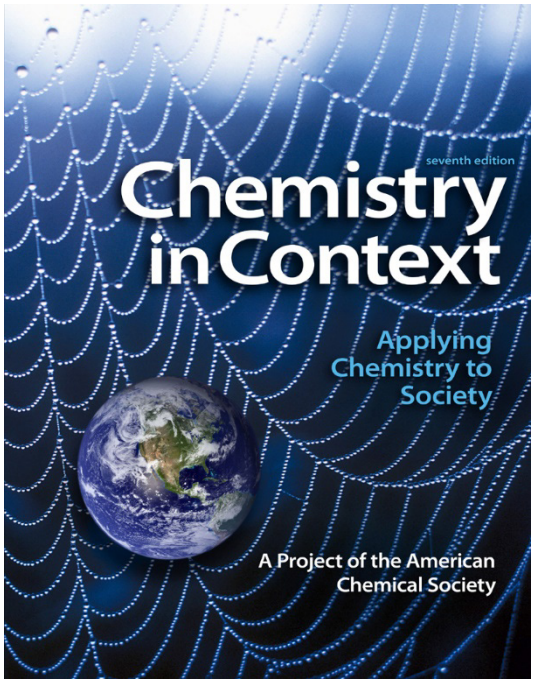
*Global Warming: The Complete Briefing 5th Edition* by John Houghton

*Paris Climate Agreement: Beacon of Hope* by Ross Salawitch, Tim Canty, Austin Hope, Walt Tribett, and Brian Bennett

https://www2.atmos.umd.edu/~rjs/class/fall2022/readings/Chem_in_Context_2011.pdf

**Must use what to open? _____**

Required Textbook: *Chemistry in Context: Applying Chemistry to Society*, American Chemical Society $\Rightarrow$ **7th edition !**




**Chemistry in Context : Applying Chemistry to Society, 7/e**

**American Chemical Society (ACS)**
**Catherine H. Middlecamp, University of Wisconsin--Madison**
**Steven W. Keller, University of Missouri--Columbia**
**Karen L. Anderson, Madison Area Technical College**
**Anne K. Bentley, Lewis & Clark College**
**Michael C. Cann, University of Scranton**
**Jamie P. Ellis, The Scripps Research Institute**

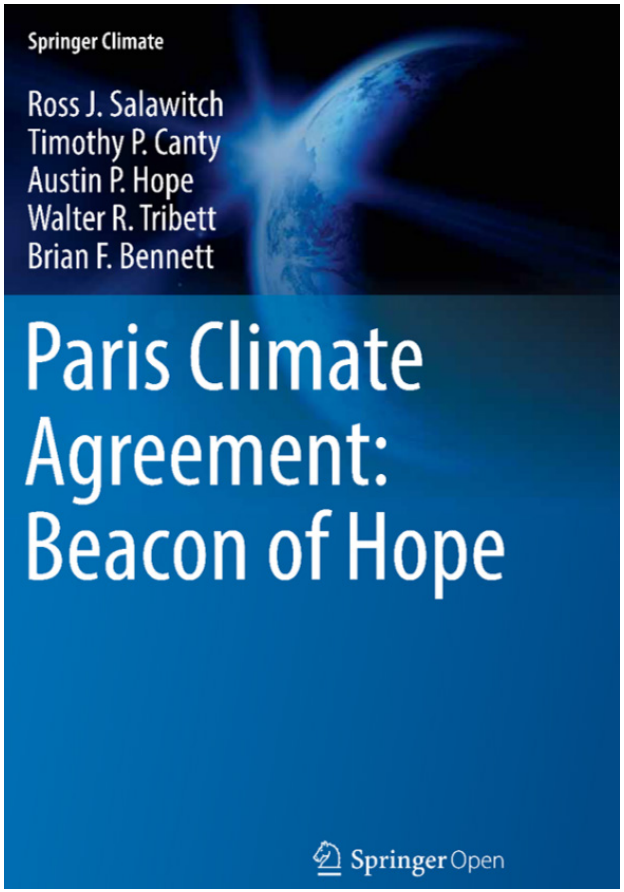
The author team truly benefitted from the expertise of a wider community. We extend our thanks to the following individuals for the technical expertise they provided to us in preparing the manuscript:

Mark E. Anderson, University of Wisconsin–Madison
David Argentar, Sun Edge, LLC
Marion O'Leary, Carnegie Institution for Science
Ross Salawitch, University of Maryland
Kenneth A. Walz, Madison Area Technical College

- Active used book market for 7th edition, since release of 8th, 9th & now 10th editions
- Changes from edition to edition are minor: we will use 7th edition to save you $$$
- If you collect text books for future reference, please note this book is more of a "tutorial" than an indispensable reference book, so probably best to check out free PDF to see if the book is worth buying
- If you feel compelled to permanently keep all of your textbooks, you are welcome to acquire your own copy of *Chemistry in Context* either from sellers such as Amazon
- Finally, I have many used hard copies of the book. Students are welcome to "rent" one of these for $20, which will be refunded upon return of the book at the end of the semester.

Numerous readings from: *Paris Climate Agreement: Beacon of Hope*

by Ross Salawitch, Tim Canty, Austin Hope, Walt Tribett, and Brian Bennett




On 11 November 2014, a remarkable event occurred. President Barack Obama of the United States and President Xi Jinping of China announced a bilateral agreement to reduce the emission of greenhouse gases (GHGs) that cause global warming by their respective nations. On 12 December 2015, a year and a month later, representatives of 195 countries attending the 21st Conference of the Parties of the United Nations Framework Convention on Climate Change meeting in Paris, France, announced the Paris Climate Agreement.

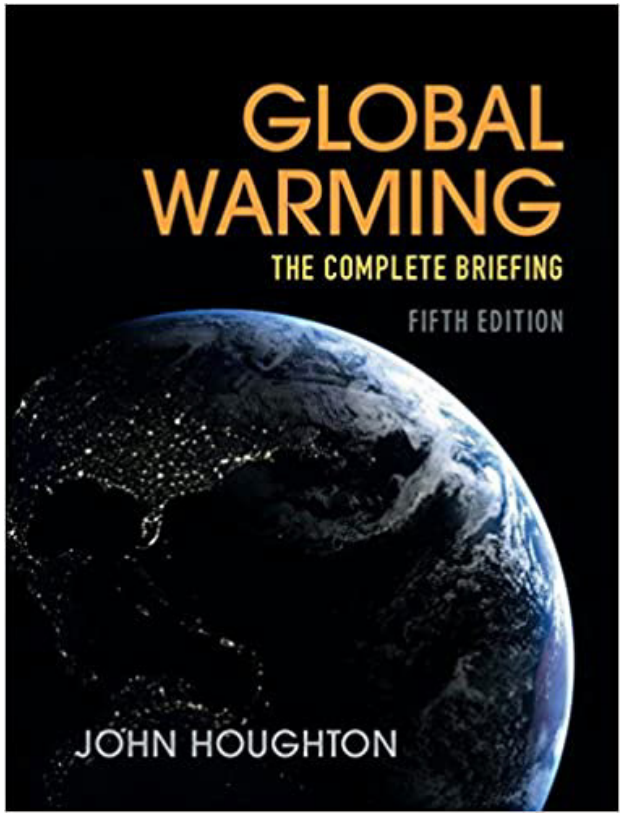
The goal of the Paris Climate Agreement is to limit the future emission of GHGs such that the rise in global mean surface temperature will be no more than 1.5 °C (target) or 2.0 °C (upper limit) above the pre-industrial level. The Paris Climate Agreement utilizes an approach for reducing the emissions of GHGs that is distinctly different than earlier efforts. The approach for Paris consists of a series of Intended Nationally Determined Contributions (INDCs), submitted by the world's nations, reflecting either a firm commitment (unconditional INDCs) or a plan contingent on financial and/or technological support (conditional INDCs).

Here we provide an analysis of the Paris Climate Agreement written for two audiences. The first audience is the bewildered public. Hardly a day goes by without some newsworthy item being reported on climate change. Often the stories are contradictory, tainted by parochialism, skepticism, and extremism by not only the conservative and liberal media but also the camps of so-called believers and deniers. Our book goes back to basics, outlining what is known and not known about climate change. If we have been successful, this book will enable readers to advance their own understanding of this topic, in a manner that will assist in the proverbial "separation of the wheat from the chaff" with regard to climate change.

Our second audience is the women and men who are charting the response of the world to the threat of global warming. As is clear from the title of this book, we believe the Paris Climate Agreement is truly a Beacon of Hope. The Agreement has been severely criticized by some scientists, even a few prominent in the field of climate change. In this book, we closely examine the behavior of the computer models commonly used to inform climate change policy. This examination will be eye opening to many. We urge policy makers to seek their own independent assessment of the veracity of the global warming projections that are being used to inform policy.

- Book published via open access, so text is freely available
- Culmination of many years worth of research initially motivated by this class & AOSC 652
- Can obtain from https://link.springer.com/book/10.1007/978-3-319-46939-3

Numerous readings as well as: *Global Warming: The Complete Briefing* (Fifth Edition) by Sir John Houghton

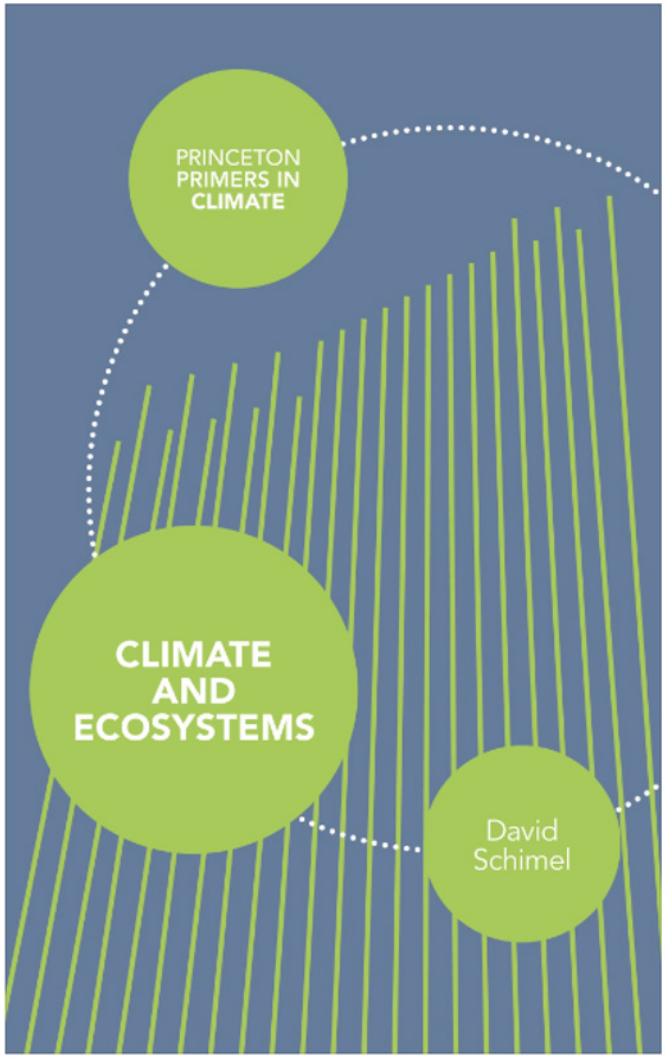




https://twitter.com/hannahmmalcolm/status/1250778555505655808

- Selected readings will be provided in password protected files (ATL2316)
- If you like the style of this book, please consider purchasing for your library
- Can purchase from this link.

Required Textbook: *Climate and Ecosystems*
David Schimel
Princeton Primers In Climate

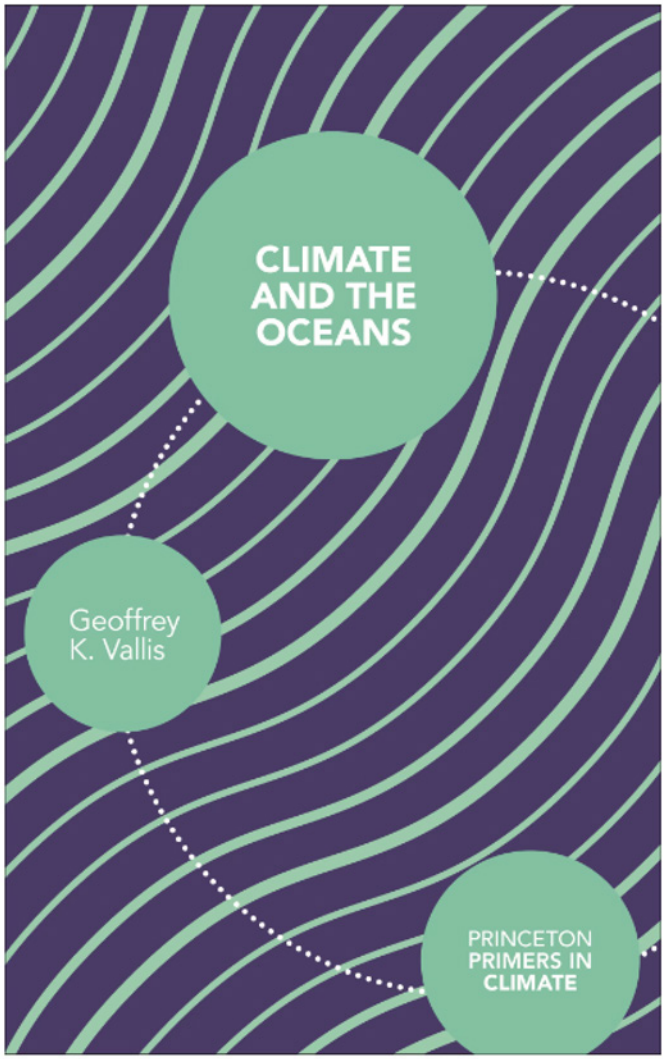



How does life on our planet respond to — and shape — climate? This question has never been more urgent than it is today, when humans are faced with the daunting task of guiding adaptation to an inexorably changing climate. This concise, accessible, and authoritative book provides an unmatched introduction to the most reliable current knowledge about the complex relationship between living things and climate.

***Using an Earth System framework***, David Schimel describes how organisms, communities of organisms, and the planetary biosphere itself react to and influence environmental change. While much about the biosphere and its interactions with the rest of the Earth System remains a mystery, this book explains what is known about how physical and chemical climate affect organisms, how those physical changes influence how organisms function as individuals and in communities of organisms, and ultimately how climate-triggered ecosystem changes feed back to the physical and chemical parts of the Earth System.

https://press.princeton.edu/books/paperback/9780691151960/climate-and-ecosystems

Required Textbook: *Climate and The Oceans*
Geoffrey Vallis
Princeton Primers In Climate




The oceans exert a vital moderating influence on the Earth's climate system. They provide inertia to the global climate, essentially acting as the pacemaker of climate variability and change, and they provide heat to high latitudes, keeping them habitable. Climate and the Oceans offers a short, self-contained introduction to the subject. **This illustrated primer begins by briefly describing the world's climate system and ocean circulation and goes on to explain the important ways that the oceans influence climate.** Topics covered include the oceans' effects on the seasons, heat transport between equator and pole, climate variability, and global warming. The book also features a glossary of terms, suggestions for further reading, and easy-to-follow mathematical treatments.

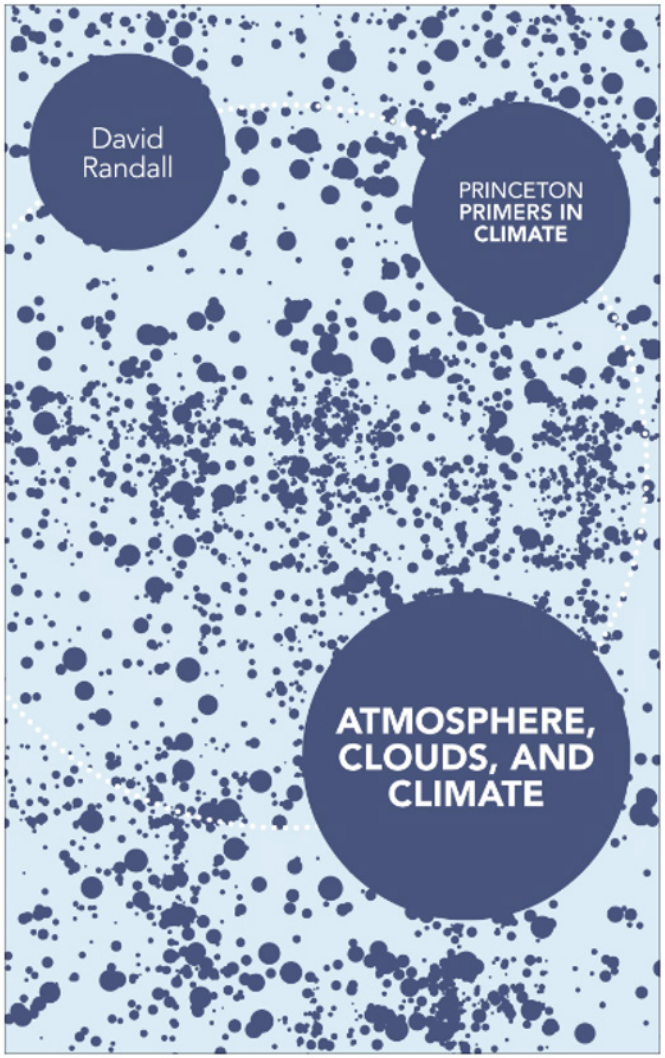
Climate and the Oceans is the first place to turn to get the essential facts about this crucial aspect of the Earth's climate system. Ideal for students and nonspecialists alike, this primer offers the most concise and up-to-date overview of the subject available.

The best primer on the oceans and climate

- Succinct and self-contained
- Accessible to students and nonspecialists
- ***Serves as a bridge to more advanced material***

https://press.princeton.edu/books/paperback/9780691150284/climate-and-the-oceans

Required Textbook: *Atmosphere, Clouds, and Climate*
David Randall
Princeton Primers In Climate



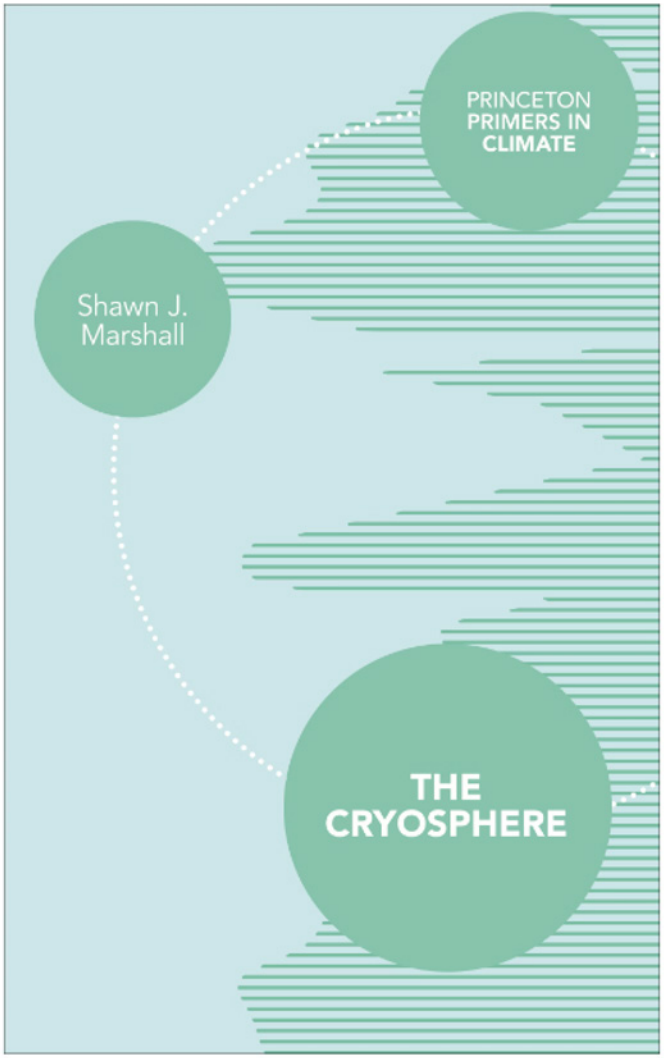

The atmosphere is critical to climate change. It can amplify shifts in the climate system, and also mitigate them. This primer offers a short, reader-friendly introduction to these atmospheric processes and how they work, written by a leading expert on the subject.

Giving readers an overview of key atmospheric processes, David Randall looks at how our climate system receives energy from the sun and sheds it by emitting infrared radiation back into space. ***The atmosphere regulates these radiative energy flows and transports energy through weather systems such as thunderstorms, monsoons, hurricanes, and winter storms. Randall explains how these processes work, and also how precipitation, cloud formation, and other phase changes of water strongly influence weather and climate.*** He discusses how atmospheric feedbacks affect climate change, how the large-scale atmospheric circulation works, how predicting the weather and the climate are fundamentally different challenges, and much more.

Authoritative and concise, *Atmosphere, Clouds, and Climate* features a glossary of terms, suggestions for further reading, and easy-to-follow explanations of a few key equations. This accessible primer is the essential introduction to atmospheric processes and the vital role they play in our climate system.

https://press.princeton.edu/books/paperback/9780691143750/atmosphere-clouds-and-climate

Required Textbook: *The Cryosphere*
Shawn Marshall
Princeton Primers In Climate




The cryosphere encompasses the Earth's snow and ice masses. It is a critical part of our planet's climate system, one that is especially at risk from climate change and global warming. *The Cryosphere* provides an essential introduction to the subject, written by one of the world's leading experts in Earth-system science.

In this primer, glaciologist Shawn Marshall introduces readers to the cryosphere and the broader role it plays in our global climate system. After giving a concise overview, he fully explains each component of the cryosphere and how it works — seasonal snow, permafrost, river and lake ice, sea ice, glaciers, ice sheets, and ice shelves. ***Marshall describes how snow and ice interact with our atmosphere and oceans and how they influence climate, sea level, and ocean circulation. He looks at the cryosphere's role in past ice ages and considers the changing cryosphere's future impact on our landscape, oceans, and climate***.

Accessible and authoritative, this primer also features a glossary of key terms, suggestions for further reading, ***explanations of equations, and a discussion of open research questions in the field***.

https://press.princeton.edu/books/paperback/9780691145266/the-cryosphere

# Organization Details

- Admission Tickets (AT) (30%)
  - short set of questions, related to lecture; *completed prior to the start of each class*
  - posted on web page; straightforward if reading has been done
  - graded on a 10 point basis; *lowest three scores will be dropped*
  - please complete on Canvas and email me if you are having a problem with Canvas
- Problem Set (10%)
  - posted on web page and announced in class at least 1 week before due date
  - prescribed "late penalty" and final receipt date: will not be accepted after solutions have been handed out (typically within ~7 days of due date)
- Exam (20%)
  - **one in-class exams (early semester)**
  - exam will tend strongly towards understanding of concepts via essay-like answers whereas problem set will tend strongly towards quantitative understanding
- In Class Presentation (20%)
  - one in-class presentation on a topic of your interest, from one or two chapters from a **Princeton Primers in Climate** book
  - Will take place starting approximately 13 Oct.
- Presentation of final project (10%)
  - Initially thought we'd have 10 min presentations
  - If we stay at 8 students, will move to 30 min presentations, 2 per class meeting
- Final paper (10%)
  - 6 to 8 pages single spaced, with references and a few figures, on topic of final project
  - Originally gave 8 Dec 2022 due date for everyone; might stagger to make paper due within a week of each presentation

# Organization Details, Continued

- Readings
  - All readings, except those from required text, will be posted on class webpage I maintain
  - Handouts of selected readings will be provided
  - Publicly available PDF files will be “unprotected”
  - Copyright protected PDF files will be protected, using **password _____**
- Additional Readings
  - Provided for many lectures for students who would like more in depth info, to enhance learning experience for motivated students
- Email
  - ***Please use AOSC 680 at start of subject line of all class-related email***

# Next Two Lectures Very Important

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**Geology 101 rolled into 75 minutes, with emphasis on Earth System Science**

**Road map of the material to be covered in the first 1/3 of this class, which is absolutely essential to modern Earth System Science**

**https://www2.atmos.umd.edu/~rjs/class/fall2022**