Syllabus
Physics of the Global Climate Change
(Physics 2450)
Fall Semester 2024

Instructor Information:

Instructor:	Prof. Jens Oberheide http://globaldynamics.sites.clemson.edu/index.html
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Office Hours:	Tuesday 2–3 pm. Additional appointments can be made through email on an as needed basis.
Class Hours:	Tu & Th 11–12:15, Kinard 201; you may leave class if Prof. Oberheide has not arrived after 15 minutes
Teaching Asst:	Mukta Neogi mneogi@clemson.edu. Her office hours are Mondays from 10–11 am, Kinard 310B. Additional appointments can be made through email requests to Mukta.

Course Mode of Delivery:

This section gives you the big picture of how we are going to do the course. Most importantly, talk to me if anything comes up that impacts your ability to meet course expectations. ***I can only help if you let me know!***

The most important link is https://clemson.instructure.com/courses/231379/modules (Course Canvas site, Modules section). You will find all material and assignments there, including what to do, and when and where. It is your responsibility to be aware of assignments and deadlines. ***You should expect 2-3 hrs/week of time commitment in addition to the class time to succeed in the course.***

Course mode of delivery: This is a lecture course based on a very popular textbook. We will use a blended mode of delivery. You will prepare before class by reading assigned book chapters and lecture notes, and answer study questions (knowledge check). In-class lecturing will be used for application of content, discussion, and engaging in exercises and exploring web-based resources and models. ***What this means is the following:***

(1) Before class, you will need to work through slides and reading assignments (provided for each Module) and ***do the included knowledge check***. You can do this at a time of your choosing, but it must be within the two days before the class. This is to understand the foundations, and the knowledge check will contribute to your grade. I find it more useful to have you work through the slides at your own pace instead of sitting in front of a

computer screen and listening for more than an hour to a lecture without a lot of interaction. The knowledge check will allow you to make sure that you got the main points. I rather spend class time to answer questions and do interactive applications with you.

(2) <u>During class</u>, we will do interactive applications through the AMS eInvestigations Manual (see required text below), the RealTime Climate Portal and other tools, and I will answer questions. For example, we will analyze observations made at Clemson University for many decades on climate trends, run interactive physics models to see how adding more carbon dioxide or methane changes temperature, and also more economics based models to understand the so-called social cost of carbon, i.e, how to put a $ amount on greenhouse gas emissions. All students must be logged into Canvas during the scheduled class hours, to allow for engagement. ***I will also re-iterate on difficult concepts and help with test preparation, give time for questions, etc.*** You will also do in-class quizzes through Canvas that will contribute to your grade. Specific instructions will be provided in each of the modules on Canvas.

Course Information

Course Rationale: Climate change will be, if not already, the environmental issue of the 21st century. This course aims to address the whole complexity of climate change with the focus upon the physics of climate change and impacts on the earth system. This course is a 3-credit elective to fulfill the Global Challenges requirement in the new Crossings Education Curriculum. For students still under the old curriculum, the course fulfills the General Education competencies "Natural Science (NS, 3 credits)" and "Science and Technology in Society (STS, 3 credits)".

Some important questions addressed in this course are:

- What is the scientific basis for our understanding of climate change?
- What are the sources of emissions of greenhouse gases?
- What changes in climate might we expect over the coming century and what might be the impacts for human wellbeing?
- What technologies exist or might be developed that could mitigate climate change?
- How do private, national and world economies respond to the challenge?
- How are public opinions formed and how do they vary in time?
- What is the role of scientists in the formulation of strategic goals and policy? What is a scientific consensus?

Objectives/Learning Outcomes and General Education Competencies: You will be expected to show mastery of a variety of concepts drawn from the Earth sciences and physics (but I am not going to drown you in equations). You will be able to explain the

relevance of these concepts for our present understanding of human-caused climate change and for the viability of different proposed solutions for adaptation and mitigation.
Global Challenges Learning Outcomes: This course will address the Global Challenges Learning Outcomes "Students will demonstrate critical thinking through analysis of global challenges." And "Students will evaluate how varying perspectives influence global challenges." By the end of this course, you will be able to:

- Explain the natural and human causes of the Global Challenge climate change, including the sources of local and global greenhouse gas emissions. Because local and global energy consumption is central to greenhouse gas emissions, students will understand the global energy infrastructure in a historical context. The possible technological options and opportunities for reducing greenhouse gas emissions would be studied and critically evaluated.
- Explain and quantify the impacts of the Global Challenge climate change on the natural world and humanity, and evaluate means by which these impacts can be reduced by adaptation, mitigation, and geoengineering.
- Summarize and analyze the diverse range of policy issues related to global warming.
- Discuss how scientific knowledge is transmitted to society and the reception by different stakeholders.
- Analyze the impact of decision making and controversies among different interest groups.

Natural Sciences (up to catalog year 2021-22): Demonstrate scientific literacy by explaining the process of scientific reasoning and applying scientific principles inside and outside the classroom.

- Understand and apply physical terms and quantities like energy, power, temperature, heat, radiation and convert between different units
- Describe how the Earth's climate system works and summarize general atmosphere circulation patterns, ocean circulation patterns and climate oscillations such as the thermohaline circulation, North Atlantic Oscillation, and the El-Niño-Southern Oscillation.
- Diagram components of the Earth's carbon cycle, quantitatively describe how addition of carbon dioxide to the atmosphere through burning of fossil fuels will influence the climate, and understand the various feedback mechanisms that enter into the modeling of global climate change.
- Explain and evaluate the evidence for human-caused climate change, in the context of historical climate change, as well as the relevant scientific uncertainties and possible evidence to the contrary.
- Explain the natural and human causes of climate change, including the sources of greenhouse gas emissions. Because energy consumption is central to greenhouse gas emissions, students will understand the global energy infrastructure in a historical context. The possible technological options for reducing greenhouse gas emissions would be studied and evaluated.

- Explain and quantify the impacts of climate change on the natural world, and evaluate means by which these impacts can be reduced by adaptation, mitigation, and geoengineering.

Science and Technology in Society (up to catalog year 2021-22): Demonstrate and understanding of issues created by the complex interactions among science, technology and society

- Summarize and analyze the range of policy issues related to global warming.
- Discuss how scientific knowledge is transmitted to society.
- Evaluate the successes and failures of past efforts to address climate change and evaluate prospects for future mitigation of climate change.
- Analyze the impact of ethical decision making and controversies among different interest groups.

Each of you comes to the course with differing levels of competency. By honoring course policies, attending class regularly, completing all assigned work in good faith and on time, you have the opportunity to meet these course learning outcomes.

Course Outline: The course contains twelve modules, each covering approximately one chapter in the textbook by Dessler and consisting of the following components.

- ***Lecture:*** In each lesson, you will learn the key topics from the course materials in the book by Dessler. You are expected to read the relevant text ***before each class***, work through the specified slides, and complete the knowledge test (part of your grade).
- ***Class:*** During regular ***class hours***, we will do exercises from the *eInvestigations Manual* that uses real-world data and illustrates the concepts described in the text material. We will also use interactive demonstrations that help to illustrate the concepts developed in each of the course modules, for example climate models that you can run yourself! And there will be plenty of time for discussions!
- ***Individual Assignments:*** These assignments will give you the chance to apply what you have learned and to demonstrate development of your skills related to the course content. You will complete these assignments on Canvas for each module to demonstrate your mastery of the module material. Each assignment will include questions related to the *Introduction to Modern Climate Change* textbook material, as well as an exercise from the *eInvestigations Manual* that uses real-world data and illustrates the concepts described in the text material. These assignments will be your homework grade and will be done ***after we finished a course module.***
- ***Signature Assignment:*** You will research a local or global approach to mitigate climate change and design a 1-page infographic that addresses a specific solution. Example include, but are not limited to, buildings sea walls, carbon-free energy production, reforestation, carbon capture. You will be provided with examples of infographics from different areas and instructions for effective design. The infographics specifically addresses the learning outcomes of (1) critically evaluating climate change impact reduction through adaptation, mitigation and

geoengineering, and (2) transmission of scientific knowledge to society and the reception by different stakeholders.

Directions for completing course assignments, including deadlines, are provided in the Modules area of the course Canvas site. Each module requires about 2-3 additional hours for reading, working assignments, and preparing for quizzes and tests. A detailed time table - which will be updated as the course progresses - is on Canvas in the syllabus section (linked here). The modules are:

1. Introduction to the climate problem.
2. Is the climate changing?
3. Radiation and energy balance
4. A simple climate model
5. The carbon cycle
6. Climate forcing, feedback, and sensitivity
7. Predicting climate change
8. Impacts of climate change
9. The Social Cost of Carbon
10. Fundamentals of climate change policy: adaptation, mitigation & geoengineering
11. Climate change mitigation
12. Putting everything together

Method of Teaching: This is a lecture course based upon a very popular textbook. You will prepare by reading the chapters and answer included study questions. The main points (including mathematical examples) will be reviewed and discussed in class, along with additional material. We will also engage in a number of exercises exploring various web-based models and applying the knowledge. Laptop (or smartphone with a big enough screen) with web access and calculator is required for each class. Assignments, exams, in-class quizzes are administered through Canvas.

Grading: Assignments (all through Canvas) in this course are divided into these general categories, which carry the following weight in your final grade calculations:

Category	Weight
Knowledge check – pre-class	20%
In-class quizzes – during regular class hours	15%
Homework assignments – after each module is completed	25%
Signature assignment	10%
Midterm exam	15%
Final exam	15%

There will be ***one midterm exam*** (tentative date: early-mid of Ocotber) and one ***final exam*** (Dec 11). Each exam carries a weight of 15%. The ***knowledge check*** (pre-class within a 48 hours window prior to the class time) requires a password that you will find in the slides

for the day. The two lowest knowledge check scores will be dropped for the final grade calculation. The short ***in-class quizzes*** will be related to what we did in class. The password will be provided during class. The two lowest in-class quiz scores will be dropped for the final grade calculation. You will also complete a ***homework assignment*** after we finished a module, so on a ~weekly basis, to put the lecture material and in-class exercises into context. The two lowest homework scores will be dropped for the final grade calculation. The ***signature assignment*** will be due approximately one week before the final exam week.

Late homework and knowledge checks won't be accepted if you do not give me a very good reason.

Note that the homework will be comparatively short as you already do the pre-class knowledge checks. Homework will be more focused on "comprehension".

All exams will be open book and a lockdown browser will not be required. You won't be able to find answers to the exam questions on google and I doubt that ChatGPT (which is not allowed!) would be a big help.

Letter grade: A: 90-100%; B: 80-89%; C: 70-79%; D: 60-69%; F:<60%

Required Materials: Smartphone or laptop with Canvas & Zoom Apps. ***Must bring to each class to do the attendance quiz and to interact with peers.***

Required Textbooks:

- Dessler, Andrew: *Introduction to Modern Climate Change*, 3rd ed., Cambridge University Press, 2022, ISBN 978-1-108-79387-1 (paperback), ~$35. You may also use the ebook edition. The course will follow this textbook.

- *AMS Climate Studies Manual 2024-2025*. ISBN 978-1-960459-09-1, $84. This eInvestigations Manual published by the American Meteorological Society is only available in digital format and is required for homework. A digital version of the manual can be ordered at URL: https://edubooks.ametsoc.org/CLIM-24 (or see the Clemson bookstore). This includes access to the AMS RealTime Climate Portal which we will use in the course. AMS is offering digital versions and a package that includes a softcover version and a webBook version, if you prefer a printed copy.

The digital versions of both course texts are less expensive and, in some cases, more convenient than the print versions. Please be sure that you want to take the course before deciding to purchase digital versions of the books since there are no refunds for the digital editions.

Recommended Textbook: Archer, David: Global Warming: Understanding the forecast, 2nd ed., Wiley, 2011, ISBN 978-0-470-94341, paperback, ~$40.

Web Sites: The main course web site is on Canvas, accessible at https://clemson.instructure.com/courses/231379. Module material, announcements, and assignments will be posted here. All exams will be administered through Canvas.

In addition to the main course web site, we will use the American Meteorological Society web site that is a companion to the *eInvestigations Manual* used in the course. The site (called RealTime Climate Portal) is accessible at https://edubooks.ametsoc.org/user/anonymous You will need to login in with your eInvestigations Manual credentials. That site has information about the state of the climate, links to current climate data in the format used by scientists, and links to other web sites with resource material that may be useful or of general interest. The site also has online quizzes that you can take for practice or to help you in learning terminology and course-related information. You may also want to visit "student resources" as it points you to ***internships and student organizations in climate***.

Additional useful web sites are:

http://www.andrewdessler.com Andrew Dessler's book website
http://www.ipcc.ch Intergovernmental Panel on Climate Change (IPCC)
http://climatemodels.uchicago.edu Online climate models interface

Course Policies

The following policies are the standard syllabus material. Please read completely.

Prerequisites: None. However, this is an algebra-based physics course, similar to PHYS 2000, which requires MATH 1020. Successful participation will require some algebra, manipulating numbers in scientific notation, reading and preparing graphs, and understanding text problems. I am not going to drown you in equations but if you feel very uncertain in these areas you should consider taking a different course.

Attendance Policy: This course is designed for active learning and engagement. Attendance and active participation in this course will provide the most benefit for learning. Therefore, ***attendance and participation are required*** and will be checked through the in-class quizzes. ***A student who misses more than four classes without a valid excuse may be dropped from the course.*** I am not going to penalize you if you are sick or if you have other important (valid) reasons. So, talk to me. What I won't accept is if you just stop attending/participating.

Any exam that was scheduled at the time of a class cancellation due to inclement weather will be given at the next class meeting unless contacted by the instructor. Any assignments due at the time of a class cancellation due to inclement weather will be due at the next class meeting unless contacted by the instructor. Any extension or postponement of assignments or exams must be granted by the instructor via email or Canvas within 24 hours of the weather-related cancellation.

University Policies

Academic Integrity: The Clemson University statement on academic integrity reads: "As members of the Clemson University community, we have inherited Thomas Green Clemson's vision of this institution as a "high seminary of learning." Fundamental to this vision is a mutual commitment to truthfulness, honor and responsibility, without which we cannot earn the trust and respect of others. Furthermore, we recognize that academic dishonesty detracts from the value of a Clemson degree. Therefore, we shall not tolerate lying, cheating or stealing in any form."

All infractions of academic dishonesty by undergraduates must be reported to Undergraduate Learning for resolution through that office. In cases of plagiarism instructors may use the Plagiarism Resolution Form.

Plagiarism, which includes the intentional or unintentional copying of language, structure, or ideas of another and attributing the work to one's own efforts. Graded works generated by artificial intelligence or ghostwritten (either paid or free) are expressly forbidden. See the Undergraduate Academic Integrity Policy website for additional information and the current catalog ("Academic Regulations" section) for the policy. Send questions to UGSintegrity@clemson.edu.

Student Accessibility Statement: Clemson University values the diversity of our student body as a strength and a critical component of our dynamic community. Students with disabilities or temporary injuries/conditions may require accommodations due to barriers in the structure of facilities, Students who experience a barrier to full access to this class should let the instructor know and are encouraged to request accommodations through SAS (Student Accessibility Services) as soon as possible. To request accommodations through SAS, please see this link: www.clemson.edu/academics/student-accessibility-services/how-to-register/requesting-accommodations. You can also reach out to SAS with questions by calling 864-656-6848, email CUSAS@clemson.edu or visiting SAS at the ASC Suite 239. Contact the office for the most updated drop-in schedule if you would prefer not to schedule an appointment.

Clemson University Title IX Statement: Clemson University is committed to a policy of equal opportunity for all persons and does not discriminate on the basis of race, color, religion, sex, sexual orientation, gender, pregnancy, national origin, age, disability, veteran's status, genetic information or protected activity (e.g., opposition to prohibited discrimination or participation in any complaint process, etc.) in employment, educational programs and activities, admissions and financial aid. This includes a prohibition against sexual harassment and sexual violence as mandated by Title IX of the Education Amendments of 1972. This policy is located at http://www.clemson.edu/campus-life/campus-services/access/title-ix/. Ms. Alesia Smith is the Clemson University Title IX Coordinator. She is also the Assistant Vice President of Equity Compliance. Her office is located at 223 Brackett Hall, 864.656.3181. Remember, email is not a fully secured method of communication and should not be used to discuss Title IX issues.

Emergency Preparedness Statement: Emergency & Safety Procedures have been posted in all buildings and on elevators. Students should be reminded to review these procedures for their own safety. All students and employees should be familiar with guidelines from Clemson University Public Safety. Clemson University is committed to providing a safe campus environment for students, faculty, staff, and visitors. As members of the community, we encourage you to take the following actions to be better prepared in case of an emergency: 1. Ensure you are signed up for emergency alerts (CU Alerts). Alerts are only sent whenthere is a potential threat to safety, a major disruption to campus services, and for once-monthly tests. 2. Familiarize yourself with all possible exits, safer locations, and other key information onthe emergency evacuation maps in this building and those that you visit regularly. 3. Make a plan for how you would Run, Hide, and Fight in case of an active threat in thisbuilding and those that you visit regularly. Run – What are all the possible exits in this building, and the routes to them? Hide – What are the potential hiding locations in this room and building that are outof sight of doors and windows, how do you lock the door(s), how would youbarricade the door(s) and windows, and where do you turn off the lights? Fight – What tools are available in this room and building, should you have to fight? 4. Learn what you can do to prepare yourself for the hazards that affect our locations(https://www.clemson.edu/cusafety/emergency-management/emergency-procedures/index.html). 5. Download the Rave Guardian app to your phone (https://www.clemson.edu/cusafety/cupd/rave-guardian/).