



Global Warming Science 101 (Spring 2026)

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Harvard canvas course web page for EPS/ ESE 101:

<https://canvas.harvard.edu/courses/159536>

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Administrative

Instructor: Eli Tziperman (eli@eps.harvard.edu); **TFs:** TBA. Please feel free to email or visit us with any questions.

Day, time & location: Wednesday 3–5:45, HUCE room 440, 4th floor, 26 Oxford St.

Office hours: Each of the teaching staff will hold weekly office hours; see course web page for times & place. Eli's office: 24 Oxford, museum building, 4th floor, room 456.

Course resources:

1. **Textbook:** Global Warming Science.
2. [Python Jupyter-notebooks and corresponding data sets](#).
3. [Slides](#) used in class.
4. Instructions for writing assignment for the [first](#) and for the [following](#) weeks.
5. [Guiding questions](#) for the weekly writing assignment.

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Description: An introduction to the science of global warming/climate change meant to assist students in understanding issues that appear in the news and public debates. The course is meant for STEM students with basic math preparation, not assuming prior science courses. Topics include the greenhouse effect and consequences of the rise of greenhouse gasses, including [sea level](#) rise, ocean [acidification](#), heat waves, [droughts](#), glacier melting, [forest fires](#), expected changes to [hurricanes](#), and more. An ability to critically evaluate observations, predictions, and risks will be developed throughout. The scientific basis for each subject will be covered, and students will be guided in a hands-on, in-class quantitative analysis of climate observations, models, and feedbacks using provided [Python Jupyter notebooks](#).

Requirements: In-class *participation* is required. There are *two assignments per class*: (1) a Jupyter-notebook-based workshop, (2) a one-page report addressed to the president's science adviser, explaining the problem, motivation, methods, the science results and the implications, based on the class and workshop. Address all guiding questions while maintaining a coherent structure. No more than one page, not including the 250 words summary from chatGPT, 12 pt, single spacing ([detailed guidelines](#)). Each student will serve as a *coach* in at least one class, helping other students after being prepared by the teaching staff the week before. Each group of coaches will also prepare *three-slide presentations* for two discussion classes on critically reading popular press and for the last class on the climate change science and policy.

Grading: HW, including workshop, essays, and group presentations: 75% (the lowest weekly grade—essay+notebook—will be dropped, the presentation class assignments

cannot be dropped); coaching: 10%, participation: 15%. The course may not be taken as pass/fail. Jupyter notebook and one-page report should be submitted via *Gradescope* as two separate PDFs by 2 pm on Wednesday a week after being assigned. Students may miss one class, not including one of the two discussion classes. Late arrival(s) count as missed classes and affect the course grade. Each student is allowed two up to 48-hour late submissions during the semester in addition to the drop HW implied by the grading scheme. **Regrading:** Please come to Eli's office hours **within seven days of the release of grades** if you notice an issue. For any grading-related concerns, please speak to Eli in person during office hours rather than emailing him or contacting the TFs.

Course forum: Please post questions regarding HW/lectures to the course forum on *Ed Discussions* (edstem.org) or come to office hours, rather than emailing the teaching staff. You are very welcome to respond to other students' questions.

Homework help session: a day before the HW is due, Tuesday 4–6, see location on Canvas. Come get your questions answered and help others!

Electronic homework submission: via gradescope.com: upload your submission, with code exported from Jupyter to PDF via LaTeX, & typeset essay; *tag your questions* following this [video](#). **Late submissions** lead to a reduction of 2% per minute.

Optional extra credit HW problems: These involve more challenging programming/math/ independent work (teaching staff available to help, of course). Apart from the fun of doing these problems, they may bring the total HW score to up to 110%, counting against problems you may have missed in the same or other HW assignments. . .

Course meetings: 3-hour sessions, including short lecture segments mixed with guided hands-on programming. [Group work is strongly encouraged during workshops.](#)

Recommended Prep: Basic calculus and ordinary differential equations, as covered, for example, by Math 19a or Math 21b or permission of instructor. Some previous exposure to programming (in any programming language) is assumed, and Python will be introduced as part of the course. The course will introduce the students to various science subjects, but no prior college-level science knowledge is assumed.



Programming in [Python](#), will be employed throughout the course. Students will be provided with template code ([in the form of easy-to-use Jupyter notebooks](#)) to start from and be closely guided in the weekly course workshops. **Students are requested to bring their laptops to the first class.** We will be using the FAS Jupyter server, so no software installation is needed, although students may also use [Anacoanda](#).

Textbook: “Global Warming Science: A Quantitative Introduction to Climate Change and Its Consequences”, Eli Tziperman, 2022.

Academic Integrity and Collaboration Policy: We strongly encourage you to discuss and work on homework problems with other students and with the teaching staff. However, after discussions with peers or consulting generative AI, you need to work through the problems yourself and ensure that any answers you submit for evaluation are the result of your own efforts, reflect your own understanding, and are written in your own words. In the case of assignments requiring programming, you need to write and use your own code; code sharing is not allowed. You must appropriately cite any books, articles, websites, lectures, generative AI, etc. that have helped you with your work.

Lecture order

Lecture order this semester; see below for outlines of lectures:

1. Introduction
2. Hurricanes
3. The greenhouse effect
4. Sea level rise
5. Clouds
6. Temperature
7. Ocean Circulation
-  Spring break 
8. Critically reading popular press articles about climate change science
9. Droughts
10. Sea ice
11. Ocean acidification
12. Forest fires
13. The last class! (Mis)using climate science in setting policy

Lecture outline

1. Logistics, course requirements; overview of the course and [an introductory Jupyter notebook with python basics](#).
2. **The greenhouse effect**
 - (a) Energy balance, the greenhouse effect in a two-layer model.
 - (b) Emission height, atmospheric lapse rate, response to greenhouse gas increase.
 - (c) Black body radiation.
 - (d) What are greenhouse gases, and how do they absorb radiation:
 - Vibrational and rotational modes.
 - Energy levels, absorption lines, absorption windows.
 - Pressure and Doppler broadening.
 - Different greenhouse gases compared via their Greenhouse Warming Potential.
 - (e) Water vapor feedback to increased CO₂.
3. **Temperature**
 - (a) Equilibrium climate sensitivity.
 - (b) Transient climate sensitivity and the role of the ocean.
 - (c) Polar amplification.
 - (d) Natural variability and “hiatus” periods.
 - (e) Stratospheric cooling.
4. **Sea level rise**
 - (a) The historical record and future projections:

- Exiting from the Little Ice Age vs. anthropogenic global warming.
- Decadal variability.
- Global vs. regional.
- Future projections.
- (b) Global mean sea level change:
 - Thermal expansion.
 - Glacier and ice sheet mass balance.
 - Land water storage.
- (c) Regional sea level change:
 - Wind stress.
 - Atmospheric sea level pressure.
 - Ocean circulation.
 - Land erosion.
 - Gravitational effects.

5. Clouds

- (a) Cloud types: high/ low, water/ ice.
- (b) Shortwave (SW) and longwave (LW) cloud radiative forcing (CRF).
- (c) How clouds form, atmospheric convection.
- (d) Cloud microphysics: fall speed of cloud droplets, cloud dissipation, droplet size distribution, hygrometer types, aerosols.
- (e) Cloud feedbacks and warming uncertainty.

6. Ocean acidification

- (a) The ocean carbonate system.
- (b) Alkalinity, total CO_2 , pH.
- (c) The effect of increasing atmospheric CO_2 on ocean acidity and on calcium carbonate dissolution.
- (d) Long-term decline of anthropogenic CO_2

7. Ocean circulation collapse

- (a) The Atlantic Meridional Overturning Circulation.
- (b) Ocean temperature, salinity, density.
- (c) Multiple equilibria, stability, tipping points, hysteresis.
- (d) Consequences of meridional circulation collapse
- (e) Observations, has the ocean's circulation started collapsing? Projections.

8. Hurricanes

- (a) The big factors: Sea Surface Temperature (SST), wind shear.
- (b) Have hurricanes become stronger already: correlation with SST.
- (c) Potential intensity: Clausius-Clapeyron relation, hurricane energetics, and future intensification.

- 9. A special course session on **critically reading popular press articles about climate change**, first class after spring break: The individual and group

assignments, in this case, are due before class; see reading material and guidelines [here](#).

10. Sea ice

- (a) Decline of Arctic ice extent, area, volume, and age.
- (b) Recent decline of sea ice around Antarctica.
- (c) Why do these changes occur, and what is the impact?
- (d) Sea-ice feedbacks: albedo, age and melt ponds, thickness and insulation, thickness and mobility due to storms.
- (e) Detection of climate change.
- (f) Future projections.

11. Greenland and Antarctica

- (a) Observed changes to Greenland and Antarctica.
- (b) Surface Mass balance (SMB): Ablation vs accumulation, positive degree days (PDD).
- (c) SMB as a function of height: elevation-desert effect; lapse rate and reduced ablation; temperature precipitation feedback.
- (d) Calving: yield stress, floating criteria, hydro-fracturing in ice shelves.
- (e) Marine Ice Sheet Instability (MISI).
- (f) Basal heat budget and meltwater production.
- (g) Ice stream acceleration, lubrication by basal water, melt ponds, and Moulins.
- (h) Ice ages
- (i) Observations of current trends and future projections.

12. Mountain glaciers

- (a) The observed retreat over the past 150 years, acceleration in recent decades.
- (b) Surface mass balance, equilibrium line, accumulation, and ablation zones.
- (c) Glaciers as climate proxies: ice cores and glacier length records.
- (d) Glacier ice flow and retreat due to warming and changes in surface mass balance.
- (e) Retreat due to exit from Little Ice Age vs. anthropogenic climate change.

13. Droughts and precipitation

- (a) Precipitation, evaporation, and soil moisture.
- (b) Droughts driven by remote SST changes due to natural variability modes such as El Niño or the Indian Ocean dipole.
- (c) Reconstructing past droughts, tree rings, and the detection of anthropogenic climate change.
- (d) Future projections: two case studies, Sahel and South-West US.
- (e) Understanding precipitation projections:
 - i. The “wet getting wetter, dry getting drier” global-scale projection.
 - ii. Expansion of the Hadley cell and shift of desert bands.
 - iii. Strengthening of extreme precipitation events.
- (f) Bucket model for soil moisture.

14. **Heatwaves**

- (a) Heat waves as weather events, location-specific threshold temperature, and duration.
- (b) Processes: high pressure aloft, subsidence, surface winds, clear sky and enhanced shortwave radiation, dry soil, heat stress.
- (c) Heat stress and human health effects
- (d) Projections: anticipated changes to amplitude, frequency, duration, and the total number of heatwave days.
- (e) Understanding the projected shift in heatwave statistics.

15. **Forest fires**

- (a) Fuel aridity and fire weather indices.
- (b) Non-climate human influences: ignition, fuel, and fire suppression management, population increases.
- (c) Climate factors: drought, temperature, prior-year cold season precipitation, winds, vapor pressure deficit.
- (d) Fires enhanced by climate variability modes and teleconnections vs by climate change.
- (e) Test cases: southwestern US and Australia.

16. **Last class! Using climate science in setting policy.** The individual and group assignments, in this case, are due before class; see guidelines and reading material [here](#).