

Carnegie Mellon University
Engineering and Public Policy / Civil & Environmental Engineering
Climate Change Science and Adaptation
CEE 12-766 / EPP 19-429 / EPP 19-629

INSTRUCTOR

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TEACHING ASSISTANT

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When sending emails, please ensure that you copy both Yuchuan and me.

Overview

This course consists of four parts. The first part will provide a primer for those who are curious about the physical mechanisms by which climate is determined, and by which climate change occurs. The treatment of these mechanisms will not be overly quantitative, and no prior knowledge of meteorology or atmospheric science is assumed. The second part will describe the projected consequences of climate change; and those that are already occurring. This part will also familiarize students with how societies might adapt to these changes. The third part will explore (and critique) some of the tools that decision-makers use to quantify and compare the damages caused by these consequences. The final part of the course will discuss some of the technologies that could be deployed to stave off dangerous climate change.

Prerequisites

- There are no pre-requisite courses
- College-level physics, basic calculus, and basic chemistry are required.
- Students from outside of CIT should have graduate standing and be comfortable with quantitative analysis.

Learning objectives

- Students should be able to accurately describe the conclusions (and limitations) of literature on the causes and consequences of climate change, and should know where to go to seek more detailed information
- Students should be able to run simple climate models, and offer high-level explanations of the relationship between the inputs and outputs of such models

- Students should be able to describe the consequences of climate change, and different approaches to mitigating it.
- Students should be able describe and apply the methods used to quantify the damages caused by climate change, and the costs of mitigation. They should also be able to demonstrate an awareness of the limitations of such methods.

Course structure

- **Part I**, Classes 1-11: The physics of climate, and our current understanding of climate change.
- **Part II**, Classes 12-20: The observed and anticipated changes associated with a warming climate, and what can be done to adapt to such changes
- **Part III**, Classes 21-23: Some tools available to analysts to assess, quantify, and compare the various kinds of damages that climate change costs
- **Part IV**, Classes 24-29: How can we prevent dangerous climate change?

Grading

- There will be no final exam or final project
- **Quizzes (Q)**: Each week, starting with Class 2 on Wednesday, Aug 30, there will be a 2-point, 20-minute quiz. The quiz will cover materials taught that week, including any **mandatory** readings (see below). *Bring calculators*. The exception will be the week of September 24, when we will have a mid-term. As such, there will be 14 quizzes. For graduate students, who are taking the course for 12 credits, the lowest two (2) scores will be dropped. For undergraduates, the three (3) lowest scores will be dropped.
- **Presentations (P)**: Students who are taking the class for 12 credits are required to make one presentation on a topic related to the course. Presentations will commence on October 15 and must be on topics covered on or after that date. No more than two students will be allowed to present on a single topic – assignments will be on a first-come, first-served basis. The date on which the presentation occurs will be determined by the topic: e.g., a student wishing to present on transportation must be prepared to do so on Nov 29. Students are encouraged to reach out to the course instructor and TA early to let them know which topics they would like to present on. Students should present based on an interesting paper on the topic. Basing the presentation on one of the papers that is listed on the syllabus is allowed but is not mandatory. Discuss with the instructor to figure out what paper to present. Presentations will count for 10 points.
- **Running a climate model (M)**: Starting October 8, students will begin a two-week assignment, where they will use and draw conclusions from a basic climate model (we will use either edGCM or GCAM). It will count for 10 points.
- **Short essays (E)**: Starting October 15, the course instructor will provide students with a total of eight (8) essay prompts, or roughly one prompt every week. These will be based on recent news items, reports, and academic literature. Students will be asked to respond to these prompts in 300 words, within a week after the prompts are distributed. Each response will count for 5% of the grade. Write-ups will be graded based on the clarity and coherence of arguments. For those taking the class for 12 credits, the lowest one (1) score will be dropped. For those taking the class for 9 credits, the lowest three (3) scores will be dropped.
- **On-line participation**: For each class after October 15 (Class 14, Impacts on Health), students will be required to do some reading (see the section below on class readings). Each week, you are required to post a 300-word note on the class online forum on one reading before 6:30pm on the day of the class. For example, you should post on one of the

readings that are part of the October 15 “Impacts of Health” class before 6:30pm on Monday, October 15. Altogether, these posts will count for 10 points. Each post can be a [critical summary](#) of the article or a counter-argument. Do not make your post longer than 300 words.

A summary of the grading scheme for this class is given below

	Number of prompts	Points per prompt	Undergraduates		Graduates	
			Required responses	Total points	Required responses	Total points
Mid-term	1	20	1	20	1	20
Presentation	1	10	0	0	1	10
Climate model	1	10	1	10	1	10
Quizzes	14	2	11	22	12	24
Essays	8	5	5	25	7	35
Online participation	1	10	1	10	1	10
				87		109

Cheating and plagiarism

Cheating or plagiarism will result in an automatic failure of the class and report of behavior to the student’s department head. We will follow CMU’s policy on [cheating](#) and [plagiarism](#), reprinted here for ease.

According to the University Policy on Academic Integrity, cheating "occurs when a student avails her/himself of an unfair or disallowed advantage which includes but is not limited to:

- Theft of or unauthorized access to an exam, answer key or other graded work from previous course offerings.
- Use of an alternate, stand-in or proxy during an examination.
- Copying from the examination or work of another person or source.
- Submission or use of falsified data.
- Using false statements to obtain additional time or other accommodation.
- Falsification of academic credentials."

In academic life, cheating can include copying someone else’s work, having someone else complete an assignment or take an exam for you, or stealing an exam or paper. Paying other students to do your work or buying papers is also prohibited. Submitting or using falsified data constitutes cheating as does lying to obtain additional time or other accommodation. And finally, falsifying academic credentials including but not limited to internship documentation, letters of recommendation, transcripts, and diplomas is also considered to be a violation of university policy.

According to the University Policy on Academic Integrity, plagiarism "is defined as the use of work or concepts contributed by other individuals without proper attribution or citation. Unique ideas or materials taken from another source for either written or oral use must be fully acknowledged in academic work to be graded. Examples of sources expected to be referenced include but are not limited to:

- Text, either written or spoken, quoted directly or paraphrased.
- Graphic elements.
- Passages of music, existing either as sound or as notation.

- Mathematical proofs.
- Scientific data.
- Concepts or material derived from the work, published or unpublished, of another person."

In academic life, plagiarism can include failing to cite references in your work or not attributing ideas contained in your work to the original source of those ideas. It can occur when students cut and paste material from a web resource directly into their assignments or when they sample graphic or music files without attribution. Putting someone else's ideas into your own words also requires the appropriate citation or it constitutes plagiarism.

Learning Disability

If you have a learning disability documented by Carnegie Mellon's Equal Opportunity Services office that will affect your performance in this class, please let the instructor know in a timely fashion so that suitable arrangements can be made.

Readings

For Classes 1-9, students are required to read the relevant chapters of the 1994 edition of Dennis Hartmann's *Global Physical Climatology*, which is available to any CMU affiliate in electronic form at the library.

For each class from Class 10 onwards, students are required to read material that is assigned as below. In many cases, the entire class is required to read some material. Additionally, the instructor and TA will split the class into groups starting October 1 and—for many classes—one reading will be assigned to each group. These groups will remain unchanged throughout the rest of the semester. Students are expected to come to class prepared to discuss the reading material assigned to the entire class, as well as the material assigned to their particular group. For the reading material assigned to the group, students can allocate readings among group members (e.g., one member can carefully do the reading assigned to the group for the class on October 15 and brief their group mates on it; for the class on October 17, a different team mate can do the reading and brief their colleagues.)

Textbooks and references

Class materials are drawn from (among others) the following.

Part I

- Hartmann, Dennis L. *Global Physical Climatology, Volume 56*. 1 edition. San Diego: Academic Press, 1994. The textbook is freely available in electronic form at the university library:
 - <http://web.b.ebscohost.com.proxy.library.cmu.edu/ehost/detail/detail?vid=0&sid=ea86c0a0-75f0-4e2d-b0a4-6f66ef8efbbd%40sessionmgr103&bdata=JnNpdGU9ZWZwhvc3QtbGl2ZQ%3d%3d#AN=279556&db=e230xww>
- Other sources are
 - Vallis, Geoffrey K. *Climate and the Oceans*. Princeton, N.J.: Princeton University Press, 2011.
 - Randall, David. *Atmosphere, Clouds, and Climate*. First Edition edition. Princeton: Princeton University Press, 2012.
 - Archer, David. *The Global Carbon Cycle*. Princeton: Princeton University Press, 2010.

- IPCC, 2013: *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1535 pp.

Part II

- The US National Climate Assessment: <https://science2017.globalchange.gov>
- Schimel, David. *Climate and Ecosystems*. Princeton: Princeton University Press, 2013.
- IPCC, 2014: *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1132 pp.
- IPCC, 2014: *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Barros, V.R., C.B. Field, D.J. Dokken, M.D. Mastrandrea, K.J. Mach, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 688.

Part III

- Materials will be drawn from a variety of sources. The following book is an outstanding overview of the ideas that will be discussed. Morgan, M. Granger. *Theory and Practice in Policy Analysis: Including Applications in Science and Technology*. Cambridge, United Kingdom; New York, NY: Cambridge University Press, 2017. The book is available for free to CMU students at: <https://www.cambridge.org/core/books/theory-and-practice-in-policy-analysis/1EF075A251F55FFD9F1FA04A5887EF72>
You must be on campus or logged into the Andrew network some other way for the link above to work.

Part IV

- Materials will be drawn from a variety of sources. The following book is an outstanding overview of the options available to us for decarbonizing the economy and the trade-offs involved in each of those options: MacKay, David J.C. *Sustainable Energy - Without the Hot Air*. 1 edition. Cambridge, England: UIT Cambridge Ltd., 2009.

Course Schedule

1. Mon, Aug 27 – Introduction to the course and to the earth’s atmosphere
 - Crutzen, Paul J. “Geology of Mankind.” *Nature* 415, no. 6867 (January 3, 2002): 23–23. doi:10.1038/415023a.
 - Corresponds to Chapter 1 of *Global Physical Climatology*
2. Wed, Aug 29 – The Earth’s energy balance
 - Corresponds to Chapters 2, 3, 4 of *Global Physical Climatology*

Mon, Sep 3 – LABOR DAY – NO CLASS

3. Wed, Sep 5 – Hydrologic Cycle and Carbon cycle
 - Corresponds to Chapter 5 of *Global Physical Climatology*
 - Carbon cycle from Archer, David. *The Global Carbon Cycle*. Princeton: Princeton University Press, 2010.
 - Oki, T., Kanae, S., 2006. Global Hydrological Cycles and World Water Resources. *Science* 313, 1068–1072. doi:10.1126/science.1128845
 - Houghton, R.A., 2007. Balancing the Global Carbon Budget. *Annual Review of Earth and Planetary Sciences* 35, 313–347. doi:10.1146/annurev.earth.35.031306.140057
4. Mon, Sep 10 – Atmospheric circulation and the climate
 - Corresponds to Chapter 6 of *Global Physical Climatology*
 - Some material from: Randall, David. *Atmosphere, Clouds, and Climate*. First Edition edition. Princeton: Princeton University Press, 2012.
5. Wed, Sep 12 – Ocean Circulation and Climate
 - Corresponds to Chapter 7 of *Global Physical Climatology*
 - Some material from: Vallis, Geoffrey K. *Climate and the Oceans*. Princeton, N.J.: Princeton University Press, 2011.
 - Orr, J.C., Fabry, V.J., Aumont, O., Bopp, L., Doney, S.C., Feely, R.A., Gnanadesikan, A., Gruber, N., Ishida, A., Joos, F., Key, R.M., Lindsay, K., Maier-Reimer, E., Matear, R., Monfray, P., Mouchet, A., Najjar, R.G., Plattner, G.-K., Rodgers, K.B., Sabine, C.L., Sarmiento, J.L., Schlitzer, R., Slater, R.D., Totterdell, I.J., Weirig, M.-F., Yamanaka, Y., Yool, A., 2005. Anthropogenic ocean acidification over the twenty-first century and its impact on calcifying organisms. *Nature* 437, 681–686. doi:10.1038/nature04095
 - Karl, T.R., Arguez, A., Huang, B., Lawrimore, J.H., McMahon, J.R., Menne, M.J., Peterson, T.C., Vose, R.S., Zhang, H.-M., 2015. Possible artifacts of data biases in the recent global surface warming hiatus. *Science* 348, 1469–1472. doi:10.1126/science.aaa5632
6. Mon, Sep 17 – Evolution of Earth’s climate and climate sensitivity
 - Corresponds to Chapters 8 and 9 of *Global Physical Climatology*
7. Wed, Sep 19 – The Cryosphere and Natural Climate Change
 - Corresponds to Chapter 11 of *Global Physical Climatology*
 - Marshall, Shawn J. *The Cryosphere*. Princeton, N.J: Princeton University Press, 2011.
8. Mon, Sep 24 – Mid-term
 - Mid-term
9. Wed, Sep 26 – Climate models and anthropogenic climate change
 - Corresponds to Chapters 10 and 12 of *Global Physical Climatology*
 - Roe, Gerard H., and Marcia B. Baker. “Why Is Climate Sensitivity So Unpredictable?” *Science* 318, no. 5850 (October 26, 2007): 629–32. <https://doi.org/10.1126/science.1144735>.

- Allen, Myles R., and David J. Frame. “Call Off the Quest.” *Science* 318, no. 5850 (October 26, 2007): 582–83. <https://doi.org/10.1126/science.1149988>.
10. Mon, Oct 1 – Detection and attribution of climate change
- Pages 869-71 of Bindoff, N.L., P.A. Stott, K.M. AchutaRao, M.R. Allen, N. Gillett, D. Gutzler, K. Hansingo, G. Hegerl, Y. Hu, S. Jain, I.I. Mokhov, J. Overland, J. Perlwitz, R. Sebbari and X. Zhang, 2013: Detection and Attribution of Climate Change: from Global to Regional. In: *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.
 - Pages 1-14 of NAS. “Attribution of Extreme Weather Events in the Context of Climate Change,” 2016. <http://www.nap.edu/21852>.
11. Wed, Oct 3 – Climate change scenarios
- Hausfather, Zeke. “Explainer: How ‘Shared Socioeconomic Pathways’ Explore Future Climate Change | Carbon Brief.” CarbonBrief, April 19, 2018. <https://www.carbonbrief.org/explainer-how-shared-socioeconomic-pathways-explore-future-climate-change>.
 - Vuuren, Detlef P. van, Jae Edmonds, Mikiko Kainuma, Keywan Riahi, Allison Thomson, Kathy Hibbard, George C. Hurtt, et al. “The Representative Concentration Pathways: An Overview.” *Climatic Change* 109, no. 1 (August 5, 2011): 5. <https://doi.org/10.1007/s10584-011-0148-z>.
12. Mon, Oct 8 – Carbon budgets and the current state of the adaptation and mitigation measures
- Peters, Glen P., Robbie M. Andrew, Susan Solomon, and Pierre Friedlingstein. “Measuring a Fair and Ambitious Climate Agreement Using Cumulative Emissions.” *Environmental Research Letters* 10, no. 10 (2015): 105004. doi:10.1088/1748-9326/10/10/105004.
 - Watts, Nick, Markus Amann, Sonja Ayeb-Karlsson, Kristine Belesova, Timothy Bouley, Maxwell Boykoff, Peter Byass, et al. “The Lancet Countdown on Health and Climate Change: From 25 Years of Inaction to a Global Transformation for Public Health.” *The Lancet* 391, no. 10120 (February 10, 2018): 581–630. [https://doi.org/10.1016/S0140-6736\(17\)32464-9](https://doi.org/10.1016/S0140-6736(17)32464-9).
13. Wed, Oct 10 – Climate change data and impacts
- IPCC, 2014: *Summary for policymakers. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 1-32.
 - Hoar, Tim, and Doug Nychka. “Statistical Downscaling of the Community Climate System Model (CCSM) Monthly Temperature and Precipitation Projections.” *White Paper. Boulder*, 2008.

14. Mon, Oct 15 – Impact on health

- Crimmins, A., J. Balbus, J.L. Gamble, C.B. Beard, J.E. Bell, D. Dodgen, R.J. Eisen, N. Fann, M.D. Hawkins, S.C. Herring, L. Jantarasami, D.M. Mills, S. Saha, M.C. Sarofim, J. Trtanj, and L. Ziska, 2016: Executive Summary. *The Impacts of Climate Change on Human Health in the United States: A Scientific Assessment*. U.S. Global Change Research Program, Washington, DC, page 1–24. <http://dx.doi.org/10.7930/J00P0WXS>

In Groups

1. Beard, Charles B., Rebecca J. Eisen, Christopher M. Barker, Jada F. Garofalo, Micah Hahn, Mary Hayden, Andrew J. Monaghan, Nicholas H. Ogden, and Paul J. Schramm. “Ch. 5: Vector-borne Diseases.” In *The Impacts of Climate Change on Human Health in the United States: A Scientific Assessment*, 129–156. Washington, DC: U.S. Global Change Research Program, 2016. <https://doi.org/10.7930/J0765C7V>.
2. Im, Eun-Soon, Jeremy S. Pal, and Elfatih A. B. Eltahir. “Deadly Heat Waves Projected in the Densely Populated Agricultural Regions of South Asia.” *Science Advances* 3, no. 8 (August 1, 2017): e1603322. <https://doi.org/10.1126/sciadv.1603322>.
3. Trtanj, Juli, Lesley Jantarasami, Joan Brunkard, Tracy Collier, John Jacobs, Erin Lipp, Sandra McLellan, et al. “Ch. 6: Climate Impacts on Water-Related Illness.” In *The Impacts of Climate Change on Human Health in the United States: A Scientific Assessment*, 157–188. Washington, DC: U.S. Global Change Research Program, 2016. <https://doi.org/10.7930/J03F4MH4>.
4. Fann, Neal, Terry Brennan, Patrick Dolwick, Janet L. Gamble, Vito Ilacqua, Laura Kolb, Christopher G. Nolte, Tanya L. Spero, and Lewis Ziska. “Ch. 3: Air Quality Impacts.” In *The Impacts of Climate Change on Human Health in the United States: A Scientific Assessment*, 69–98. Washington, DC: U.S. Global Change Research Program, 2016. <https://doi.org/10.7930/J0GQ6VP6>.
5. McMichael, Celia, Jon Barnett, and Anthony J. McMichael. “An Ill Wind? Climate Change, Migration, and Health.” *Environmental Health Perspectives* 120, no. 5 (May 2012): 646–54. <https://doi.org/10.1289/ehp.1104375>.

15. Wed, Oct 17 – Agriculture

- [Pages 488-494](#), [505-20](#) of Porter, J.R., L. Xie, A.J. Challinor, K. Cochrane, S.M. Howden, M.M. Iqbal, D.B. Lobell, and M.I. Travasso, 2014: Food security and food production systems. In: *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 485-533

In groups

1. Challinor, A. J., et al. “A Meta-Analysis of Crop Yield under Climate Change and Adaptation.” *Nature Climate Change*, vol. 4, no. 4, 2014, pp. 287–291., doi:10.1038/nclimate2153.

- Slater, Louise J., and Robert L. Wilby. "Measuring the Changing Pulse of Rivers." *Science* 357, no. 6351 (August 11, 2017): 552–552.
<https://doi.org/10.1126/science.aao2441>.

Blöschl, Günter, Julia Hall, Juraj Parajka, Rui A. P. Perdigão, Bruno Merz, Berit Arheimer, Giuseppe T. Aronica, et al. "Changing Climate Shifts Timing of European Floods." *Science* 357, no. 6351 (August 11, 2017): 588–90.
<https://doi.org/10.1126/science.aan2506>

- Ziska, Lewis, Allison Crimmins, Allan Auclair, Stacey DeGrasse, Jada F. Garofalo, Ali S. Khan, Irakli Loladze, et al. "Ch. 7: Food Safety, Nutrition, and Distribution." In *The Impacts of Climate Change on Human Health in the United States: A Scientific Assessment*, 189–216. Washington, DC: U.S. Global Change Research Program, 2016.
<https://doi.org/10.7930/J0ZP4417>.
- Wheeler, Tim, and Joachim von Braun. "Climate Change Impacts on Global Food Security." *Science* 341, no. 6145 (August 2, 2013): 508–13.
<https://doi.org/10.1126/science.1239402>.
- Turner, Andrew G., and H. Annamalai. "Climate Change and the South Asian Summer Monsoon." *Nature Climate Change* 2, no. 8 (August 2012): 587–95.
<https://doi.org/10.1038/nclimate1495>.

16. Mon, Oct 22 – Climate change and extreme events

- Herring, Stephanie C, Nikolaos Christidis, Andrew Hoell, James P Kossss, Carl J Schreck III, and Peter A Stott. Introduction to Explaining Extreme Events of 2016 from a Climate Perspective. AMER METEOROLOGICAL SOC 45 BEACON ST, BOSTON, MA 02108-3693 USA, 2018.

In groups

- Knutson, Tom. 2017. "Global Warming and Hurricanes." Text. 2017.
<https://www.gfdl.noaa.gov/global-warming-and-hurricanes/>.
- Knutson, Thomas R, Jonghun Kam, Fanrong Zeng, and Andrew T Wittenberg. "CMIP5 Model-Based Assessment of Anthropogenic Influence on Record Global Warmth During 2016." *Bulletin of the American Meteorological Society* 99, no. 1 (2018): S11–S15.
- Sisco, Matthew R., Valentina Bosetti, and Elke U. Weber. "When Do Extreme Weather Events Generate Attention to Climate Change?" *Climatic Change* 143, no. 1 (July 1, 2017): 227–41. <https://doi.org/10.1007/s10584-017-1984-2>.
- Walsh, John E, Richard L Thoman, Uma S Bhatt, Peter A Bieniek, Brian Brettschneider, Michael Brubaker, Seth Danielson, et al. "The High Latitude Marine Heat Wave of 2016 and Its Impacts on Alaska." *Bulletin of the American Meteorological Society* 99, no. 1 (2018): S39–S43.
- Harris, R. M. B., L. J. Beaumont, T. R. Vance, C. R. Tozer, T. A. Remenyi, S. E. Perkins-Kirkpatrick, P. J. Mitchell, et al. "Biological Responses to the Press and Pulse of Climate Trends and Extreme Events." *Nature Climate Change* 8, no. 7 (July 2018): 579–87.
<https://doi.org/10.1038/s41558-018-0187-9>.

17. Wed, Oct 24 – Ecosystems

1. Peñuelas, Josep, Philippe Ciais, Josep G. Canadell, Ivan A. Janssens, Marcos Fernández-Martínez, Jofre Carnicer, Michael Obersteiner, Shilong Piao, Robert Vautard, and Jordi Sardans. "Shifting from a Fertilization-Dominated to a Warming-Dominated Period." *Nature Ecology & Evolution*, September 18, 2017, 1. doi:10.1038/s41559-017-0274-8.
2. Palmer, Margaret A., Dennis P. Lettenmaier, N. LeRoy Poff, Sandra L. Postel, Brian Richter, and Richard Warner. "Climate Change and River Ecosystems: Protection and Adaptation Options." *Environmental Management* 44, no. 6 (December 1, 2009): 1053–68. <https://doi.org/10.1007/s00267-009-9329-1>.
3. Doney, Scott C., Mary Ruckelshaus, J. Emmett Duffy, James P. Barry, Francis Chan, Chad A. English, Heather M. Galindo, et al. "Climate Change Impacts on Marine Ecosystems." *Annual Review of Marine Science* 4, no. 1 (2012): 11–37. <https://doi.org/10.1146/annurev-marine-041911-111611>.
4. Melillo, J. M., S. D. Frey, K. M. DeAngelis, W. J. Werner, M. J. Bernard, F. P. Bowles, G. Pold, M. A. Knorr, and A. S. Grandy. "Long-Term Pattern and Magnitude of Soil Carbon Feedback to the Climate System in a Warming World." *Science* 358, no. 6359 (October 6, 2017): 101–5. <https://doi.org/10.1126/science.aan2874>.
5. Pecl, Gretta T., Miguel B. Araújo, Johann D. Bell, Julia Blanchard, Timothy C. Bonebrake, I.-Ching Chen, Timothy D. Clark, et al. "Biodiversity Redistribution under Climate Change: Impacts on Ecosystems and Human Well-Being." *Science* 355, no. 6332 (March 31, 2017): eaai9214. <https://doi.org/10.1126/science.aai9214>.

18. Mon, Oct 29 – Urban adaptation and resilience – Guest Lecture by Dr. Shalini Vajjhala

1. Freas, Kathy, Laurens van der Tak, Jacqueline Kepke, Phillip Pasteris, and Patrick Karney. "Confronting Climate Change: An Early Analysis of Water and Wastewater Adaptation Costs through 2050." *Proceedings of the Water Environment Federation* 2010, no. 15 (2010): 1940–1966.
2. Alberts, Brian, Mazhar Ali Awan, and Kimberly A Gayle. "Transit and Climate Change Adaptation: Synthesis of FTA-Funded Pilot Projects," 2014.
3. Chapter 3 (pp17-40) + Chapter 4, Section D (pp47-54) from Wilbanks, Thomas J., and Steven Fernandez. *Climate Change and Infrastructure, Urban Systems, and Vulnerabilities: Technical Report for the U.S. Department of Energy in Support of the National Climate Assessment*. Island Press, 2014.
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19. Wed, Oct 31 – Stranded Assets and Conflict

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20. Mon, Nov 5 – Valuing intangibles

- Sections 5.1 - 5.5 of Morgan, M. Granger, “Theory and Practice of Policy Analysis”
- p24-28 of Driesen, David M, Robert W Adler, and Kirsten H Engel. *Environmental Law: A Conceptual and Pragmatic Approach*. Wolters Kluwer Law & Business, 2016.
- Morgan, M. Granger, Milind Kandlikar, James Risbey, and Hadi Dowlatabadi. “Why Conventional Tools for Policy Analysis Are Often Inadequate for Problems of Global Change.” *Climatic Change* 41, no. 3–4 (March 1, 1999): 271–81. <https://doi.org/10.1023/A:1005469411776>.

21. Wed, Nov 7 – Making decisions under uncertainty

In groups

1. Sections 4.1 - 4.3 of Morgan, M. Granger, “Theory and Practice of Policy Analysis”
2. Chapter 8 of Morgan, M. Granger, “Theory and Practice of Policy Analysis”
3. Abdulla, Ahmed, Inês Lima Azevedo, and M. Granger Morgan. “Expert Assessments of the Cost of Light Water Small Modular Reactors.” *Proceedings of the National Academy of Sciences* 110, no. 24 (June 11, 2013): 9686–91. <https://doi.org/10.1073/pnas.1300195110>.
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22. Mon, Nov 12 – Floods and Sea Level Rise (Guest lecture by Miriam Belblidia)

- Miriam Belblidia is a leader in floodplain management, hazard mitigation, and storm water management best practices. Miriam is a Certified Floodplain Manager (CFM),

received a Fulbright Fellowship in water management to conduct research in the Netherlands, and worked as a Hazard Mitigation Specialist for the City of New Orleans. (from: <http://www.waterworksia.com/about>)

23. Wed, Nov 14 – Mitigating Climate Change: Caps and Taxes

- Please read: <https://www.carbonbrief.org/qa-social-cost-carbon>
- Morgan, M Granger, Parth Vaishnav, Hadi Dowlatabadi, and Ines L Azevedo. “Rethinking the Social Cost of Carbon Dioxide.” *Issues in Science and Technology* 33, no. 4 (2017). <http://issues.org/33-4/rethinking-the-social-cost-of-carbon-dioxide/>.

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1. Stern, Nicholas. “Economics: Current Climate Models Are Grossly Misleading.” *Nature* 530, no. 7591 (February 24, 2016): 407–9. doi:10.1038/530407a.
2. Moore, Frances C., and Delavane B. Diaz. “Temperature Impacts on Economic Growth Warrant Stringent Mitigation Policy.” *Nature Climate Change* 5, no. 2 (February 2015): 127–31. <https://doi.org/10.1038/nclimate2481>.
3. Temple, James. “China Is Creating a Huge Carbon Market—but Not a Particularly Aggressive One.” MIT Technology Review. Accessed August 21, 2018. <https://www.technologyreview.com/s/611372/china-is-creating-a-huge-carbon-market-but-not-a-particularly-aggressive-one/>.

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4. Jenkins, Jesse D. “Political Economy Constraints on Carbon Pricing Policies: What Are the Implications for Economic Efficiency, Environmental Efficacy, and Climate Policy Design?” *Energy Policy* 69 (June 1, 2014): 467–77. <https://doi.org/10.1016/j.enpol.2014.02.003>.
5. Schmalensee, Richard, and Robert Stavins. “Lessons Learned from Three Decades of Experience with Cap-and-Trade.” National Bureau of Economic Research, 2015.

24. Mon, Nov 19— Paris agreement fits in with international law [Guest Lecture by Prof. Iris Grossmann)

Prof. Grossmann is Assistant Professor of Sustainable Technology at Chatham University’s Falk School of Sustainability. She holds an adjunct Assistant Professor affiliation with the Department of Engineering and Public Policy at Carnegie Mellon University (CMU). Dr. Grossmann’s research focuses on large-scale solar electricity networks, energy-water interdependencies and resilience to drought, urban sustainability, and regional climate change and adaptation. Dr. Grossmann holds a Ph.D. in Geoscience/Meteorology and an M.S. in Mathematics.

Wed, Nov 21 – NO CLASS: THANKSGIVING

25. Mon, Nov 26 – Renewable electricity generation

In groups

1. Pacala, S., and R. Socolow. "Stabilization Wedges: Solving the Climate Problem for the Next 50 Years with Current Technologies." *Science* 305, no. 5686 (August 13, 2004): 968–72. doi:10.1126/science.1100103.
2. IPCC, 2011: Summary for Policymakers. In: IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation [O. Edenhofer, R. Pichs-Madruga, Y. Sokona, K. Seyboth, P. Matschoss, S. Kadner, T. Zwickel, P. Eickemeier, G. Hansen, S. Schlömer, C. von Stechow (eds)], Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.
3. MacDonald, Alexander E., Christopher T. M. Clack, Anneliese Alexander, Adam Dunbar, James Wilczak, and Yuanfu Xie. "Future Cost-Competitive Electricity Systems and Their Impact on US CO₂ Emissions." *Nature Climate Change* 6, no. 5 (May 2016): 526–31. <https://doi.org/10.1038/nclimate2921>.
4. Lam, Long T., Lee Branstetter, and Inês M. L. Azevedo. "China's Wind Electricity and Cost of Carbon Mitigation Are More Expensive than Anticipated." *Environmental Research Letters* 11, no. 8 (2016): 84015. <https://doi.org/10.1088/1748-9326/11/8/084015>.
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26. Wed, Nov 28 – Nuclear energy

- Kemeny, J. C. "Saving American Democracy: The Lessons of Three Mile Island." *Technology Review* 83, no. 7 (1980): 65–75. http://inis.iaea.org/Search/search.aspx?orig_q=RN:12619003.

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1. Lovering, Jessica R., Arthur Yip, and Ted Nordhaus. "Historical Construction Costs of Global Nuclear Power Reactors." *Energy Policy* 91 (April 2016): 371–82. <https://doi.org/10.1016/j.enpol.2016.01.011>.
2. Page 6-9 and p23-55; Nordhaus, T, J Lovering, and M Shellenberger. "How to Make Nuclear Cheap." *Breakthrough Institute*, Oakland, California, 2013.
3. Abdulla, Ahmed, and M. Granger Morgan. "Nuclear Power for the Developing World I Issues in Science and Technology." *Issues in Science & Technology*, 2015. <http://issues.org/31-2/abdulla/>.
4. Ford, Michael J., Ahmed Abdulla, M. Granger Morgan, and David G. Victor. "Expert Assessments of the State of U.S. Advanced Fission Innovation." *Energy Policy* 108 (September 1, 2017): 194–200. <https://doi.org/10.1016/j.enpol.2017.05.059>.
5. Abdulla, A, MJ Ford, MG Morgan, and DG Victor. "A Retrospective Analysis of Funding and Focus in US Advanced Fission Innovation." *Environmental Research Letters* 12, no. 8 (2017): 084016.

27. Mon, Dec 3 – Transportation

In groups

1. Kaack, Lynn H., Parth Vaishnav, M. Granger Morgan, Inês L. Azevedo, and Srijana Rai. "Decarbonizing Intraregional Freight Systems with a Focus on Modal Shift."

Environmental Research Letters 13, no. 8 (2018): 083001. <https://doi.org/10.1088/1748-9326/aad56c>.

2. Banister, David, Karen Anderton, David Bonilla, Moshe Givoni, and Tim Schwanen. "Transportation and the Environment." *Annual Review of Environment and Resources* 36, no. 1 (2011): 247–70. <https://doi.org/10.1146/annurev-environ-032310-112100>.
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5. MacKay D. J. C. "Sustainable Energy – Without Hot Air" Chapter 20. Better Transport. UIT Cambridge England http://www.withouthotair.com/c20/page_118.shtml

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28. Wed, Dec 5 – Geoengineering and Carbon Capture Utilization and Storage

- Pages 1-14 of NAS. *Climate Intervention: Reflecting Sunlight to Cool Earth*, 2015. <http://www.nap.edu/download/18988>.
- Pages 1-14 of National Research Council. *Climate Intervention: Carbon Dioxide Removal and Reliable Sequestration*, 2015. <https://doi.org/10.17226/18805>.

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1. "A Process for Capturing CO2 from the Atmosphere." *Joule* 2, no. 8 (August 15, 2018): 1573–94. <https://doi.org/10.1016/j.joule.2018.05.006>.
2. Peters, Glen P., and Oliver Geden. "Catalysing a Political Shift from Low to Negative Carbon." *Nature Climate Change* 7, no. 9 (September 2017): 619–21. <https://doi.org/10.1038/nclimate3369>.
3. Azar, Christian, Kristian Lindgren, Michael Obersteiner, Keywan Riahi, Detlef P. van Vuuren, K. Michel G. J. den Elzen, Kenneth Möllersten, and Eric D. Larson. "The Feasibility of Low CO2 Concentration Targets and the Role of Bio-Energy with Carbon Capture and Storage (BECCS)." *Climatic Change* 100, no. 1 (May 1, 2010): 195–202. <https://doi.org/10.1007/s10584-010-9832-7>.
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