GEOL 095 and 195 - Climate: past, present, future
Learning Objectives

Each objective is numbered according to a modified Bloom taxonomy

1. **Factual identification** – you know what it is and how to describe it
2. **Process** – you understand how it works
3. **Prediction** – you can predict how the system will respond
4. **Interactions** – you understand complex interactions within and outside the system

**Overall Learning Objectives for the Class**

1. Be able to explain fundamental controls on Earth’s climate including: energy balance, ocean circulation, and atmospheric composition

2. Understand how and on what timescales Earth’s climate changed in the past

3. Describe and provide evidence for human impacts on the climate system

4. Predict how climate is likely to change in the future based on human impacts and what we as a global society can do to mitigate those impacts

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**Class-by-Class Learning Objectives**

Class 1 (Getting Started)
- Understand the broad outline of the course (1)
- Understand difference between 095 and 195 (1)
- Assess your knowledge of climate in the past, present and future (1,2)

Class 2 (Global Energy Balance):
- Learn something about us all – teachers and students (1)
- List the ways in which energy enters and leaves the Earth (1)
- Identify the three primary controls on global average temperature and explain how they work (1,2)
- Explain why and predict how a simple calculation of Earth’s equilibrium temperature using data on solar energy input does not equal Earth’s actual average temperature (2,3)
- Identify the fallacy underlying claims that increasing atmospheric Carbon Dioxide concentrations cannot cause global warming (4)
Class 3 (Atmospheric circulation):
• Explain why air moves in predictable patterns across the globe (1,2)
• Explain how ocean and atmospheric circulation result in the observed global distribution of climates (2,4)

Class 4 (Ocean currents):
• Draw a sketch of major ocean circulation patterns including overturning (1)
• Predict what would happen if ocean circulation were perturbed, specifically if overturning were to slow or cease (3)

Class 5 (Cryosphere & Sea Level):
• Understand ice physics sufficiently to explain why ice sheets are not simply static bodies of ice, but are complex and dynamic (2)
• Describe the processes that will lead to melting, others forms of mass loss, and/or destabilization of Earth’s two large ice sheets (2)
• Explain why predictions of sea level rise contain so much uncertainty (4)
• Understand why rising sea level is not a slowly building threat, but could create large impacts in the near future (3)

Class 6 (Forcings, Feedbacks):
• Understand how the three “knobs” of global climate (incoming solar radiation, albedo, the greenhouse effect) change over time and with human influence (1,2)
• Understand and be able to provide specific examples of how feedback systems can amplify or diminish a climate system forcing (2)
• Explain why a large, short-term perturbation to the climate system could create long-lasting effects (4)
• Describe Earth’s orbital cycles and be able to explain how they influence climate over geologic time scales of thousands to hundreds of thousands of years (1)

Class 7 (The Carbon Cycle):
• Identify carbon sinks, sources, and reservoirs and predict how they will change if people keep doing what they have been doing since the dawn of the industrial revolution (1, 3)
• Explain the difference in processes between the ‘surficial’ carbon cycle and the ‘deep’ carbon cycle (2)
• Explain why atmospheric carbon dioxide concentrations fluctuate in a consistent manner throughout the year (2)
• Diagram the interactions over time between various stocks and flows of the carbon cycle (4)
Class 8 (Recent Warming, Causes and Evidence):

- Understand and be able to plot the trend of temperature observations over the last ~100 years (1)
- Identify what climatic indicators have been used to support the conclusion that climate change is occurring on decadal time scales and how these indicators work (2)
- Explain the details of one method used to identify the source of recent atmospheric CO2 increases as caused by human activities (2)
- Describe three pieces of evidence that demonstrate how anthropogenic CO2 emissions are directly increasing the greenhouse effect (1)

Class 9 (No Class, Chris and Paul at GSA professional geology meeting)

Class 10 (Exam)

Class 11 (Paleoclimate Proxies & Archives):

- Understand the concept of how proxy data are used to reconstruct past climates (1)
- Understand the concept of a climate-proxy archive (2)
- Explain the process by which oxygen isotopes are used to discover information about past climates (2)
- Be able to interpret an oxygen-isotope record for past temperatures (4)
- Identify and provide specific examples of the challenges confronted in retrieving and analyzing climate archives (4)

Class 12 (Paleoclimate I – Industrial & Holocene):

- Understand and be able to sketch the history of global temperatures over the last ~11,000 years (1)
- Describe one hypothesized instance of changing climate influencing an early human civilization (2)
- Describe one hypothesized instance of early humans influencing climate (2)
- Be able to construct a rational argument in defense of or opposition to the hypothesis of anthropogenic climate change starting before the beginning of the industrial revolution around 1850 AD (4)

Class 13 (No Class)

Class 14 (Michael Mann Guest Lecture in class and also Burack lecture at 430 pm): 

Class 15 (Paleoclimate II – Pleistocene):

- Understand the differences in global climate 25,000 years ago compared to the present day (1)
• Explain the ‘sawtooth’ climate pattern that dominated the Pleistocene, the last 2.7 My (2)
• Explain why orbital cycles and natural climate variability cannot explain the last 100 years of climate change (4)

Class 16 (Paleoclimate III – Greenhouse to icehouse):
• Sketch and describe the global temperature record over the last ~50 million years (1)
• Describe the tools used to reconstruct this record and how each works (1,2)
• Identify and explain one hypothesis about the causes of global temperature change over the last 50 million years (2)
• Explain why information about climate over the last 50 million years is relevant to climate change today (4)

Class 17 (Paleoclimate IV – “Deep Time”)
• Understand what geologic processes modulate global climate over long geologic time scales (1)
• Describe the general global temperature trend before 50 million years ago (1)
• Identify and explain one hypothesis about the Greenhouse climate of the Cretaceous (4)
• Explain what runaway feedback system may have led to an ‘icebox’ world otherwise known as the snowball Earth (3)

Class 18 (Exam)

Class 19 (Climate Models):
• Understand the general components of physical climate models and how they are constructed (1)
• Understand what is meant by ‘Model Calibration’ and ‘Model Validation’ (1)
• Understand the tradeoffs that climate modelers face when designing models at high resolutions, over large geospatial areas, and/or over long time scales (2,4)
• Explain how data about past climates are used for model validation (2)

Class 20 (Projections I – Temperature, weather, sea level):
• Be able to list the range of possible CO₂ emission scenarios between now and 2100 used by climate scientists (1)
• Explain how climate scientists predict the atmospheric CO₂ pulse emitted by humans will be distributed among the Earth’s carbon reservoirs, and what assumptions are being made in this prediction (2, 3, 4)
• Identify and describe two rapid (decades) climate responses to the pulse of atmospheric CO₂ we are currently emitting (1, 2)
• Explain two predicted climate responses that will take place over the next ~100 years and how they will affect human societies (2, 3, 4)

Class 21 (Projections II – Tipping Points):
• Understand the concept of runaway feedbacks and system hysteresis (1)
• Define a tipping point and identify how two ‘major tipping points’ in the climate system work (1, 2)
• Explain how and why Greenland Ice Sheet melt is or is not an irreversible tipping point system (2, 3)
• Explain why Arctic Sea Ice loss is or is not an irreversible tipping point system (2, 3)

Class 22 (Projections III – Short vs. Long Term):
• Understand and explain the processes by which slow feedbacks may cause long-term (1,000-10,000 year) climate responses long after carbon emissions have declined or stopped (2)
• Identify and describe two predicted slow (1,000-10,000 year) climate responses to the pulse of atmospheric CO₂ we are currently emitting (2, 3)
• Explain the process by which two of the predicted long-term climate responses will affect human societies (4)

Class 23 (Climate Mitigation Strategies I, Mitigation and Adaptation)
• List 2 climate adaptation strategies that have so-far been proposed (1)
• List 2 climate mitigation strategies that have so-far been proposed (1)
• Predict two challenges (physical, social, or economic) facing a proposed climate adaption or mitigation strategy (3)
• Explain the difference between climate adaptation and mitigation strategies (3)

Class 24 (Climate Mitigation Strategies II, Geoengineering)
• List 4 geoengineering strategies that have so-far been proposed (1)
• Explain the process by which two of these geoengineering strategies would address the effects of climate change (2)
• Predict how a geoengineering strategy could go wrong relying on your understanding of the process by which it works (3)
• Argue for or against climate adaption, mitigation and geoengineering strategies for addressing climate change (4)

Class 25 (Climate change economics and policy):
• Identify the four primary types of climate policies that could lead to reductions in carbon emissions and explain how each works (1, 2)
• Argue the case for one type of climate policy and explain its challenges and virtues (4)
• Explain the objectives of the Paris Accord and predict its effectiveness over the next several decades (3,4)
• Explain the costs of addressing climate change now versus delaying response including various adaptations (1)

Class 26 (Exam)

Class 27 (Climate Change Denial):

• List and explain three aspects of human psychology that make it difficult for people to think about climate change (1, 2)
• Be able to debunk on the basis of science you have learned in this class at least two of the most often repeated denialist claims (1, 2, 3)
• Explain the influence that media can have on opinions/understanding of climate change (2)
• Identify and explain one purposeful disinformation campaign targeted at climate change science (2)

Class 27 (Climate Communication- How to speak to others about climate change)

• Get prepared for the final paper
• Get tips on how to do the best final paper from Guest Speaker, Josh Brown, UVM Environmental reporter
• Tell us how to make this class better for next year!