Class 2: Class Information & Global Energy Balance

- Introductions
- Clicker tests
- What are the ‘knobs’ controlling global climate?
- What makes the Earth habitable?

Learning Objectives

1. List the ways in which energy enters and leaves the Earth
2. Identify the three primary controls on global average temperature, explain how they work
3. Explain why a simple calculation of Earth’s equilibrium temperature using data on solar energy does not equal Earth’s actual average temperature
4. Identify the fallacy underlying claims that increasing atmospheric CO\textsubscript{2} concentrations cannot cause global warming
Mae Kate Campbell
mcampb22@uvm.edu
Office Hours: 1-3pm Monday in Delehanty Hall Room 314, also by appointment!
Sediment is produced as upstream landscape features erode (like this mountain!)

The sediment from all upstream sources washes into the river and gets carried along and mixed together.

We collect the sediment in river to measure the average erosion rate of the watershed!
Christopher Halsted, M.S.

PhD Student, Gund Research Fellow

chalsted@uvm.edu

Office Hours:
• After class each day (for an hour)
• Wednesday 9-11 am in Delehanty 307
Christopher Halsted, M.S.
Christopher Halsted, M.S.

PhD Student, Research Fellow

Geochemistry, Ice Sheet Reconstructions, Paleoclimatology, Climate Change

I reconstruct past ice sheet movements using geochemical techniques to interpret how climate behaved in the past and better understand how our modern-day ice sheets might respond to future warming.
FIRST GEOLOGY TRIP -- CAPE COD, c.1966
Williams College, BA 1985
Consulting Geologist ‘til 87
Grad School in Seattle ‘til 93

1986

1991, Mt. Whitney, CA
UNUSUAL SCIENCE that matters to people
COLD WEATHER (Climate) SCIENCE

BAFFIN ISLAND, NUNAVAT
Horses working in the **Snow**

**Town:** Unknown  
**County:** No_County  
**State:** Vermont

**Date:** 1941

**Description:**
The photo shows four horses working at pulling a **snow roller** with a few men on a road. Note the cleared hill slopes in the distance. Esther Munroe Swift writes on 2005-3-3: This scene looks very much like Orleans County to me. The Old Stone House Museum in Brownington has a couple of snow rollers that were used well into the 1940's to the amazement of out-of-state visitors. Loona Brogan writes on 2005-12-11: The trees present in this image support Dr. Swift's hypothesis. Directly behind the roller are a cedar tree and a white pine behind it. In the distance, while heavily cleared (probably for hay fields for dairy farming), there are thick fir-spruce forests. These are the predominant species composition in the forests of the Northeast Kingdom, though today many of these fields would have returned to forest, as dairy farmers are much fewer than in the early 20th century.
October 25th – chance to meet Arctic scientists
Clicker Test Question 1

Which one of the teaching staff did not grow up in Maryland?

A. Paul  
B. Mae Kate  
C. Chris
Clicker Test Question 2

Which one of the teaching staff has never sampled glacial boulders to understand climate change?

A. Paul
B. Mae Kate
C. Chris
Clicker Test Question 3

What readings is will be on the quiz on Tuesday

A. Mann chapter 1
B. Ruddiman chapter 1
C. Mann and Ruddiman chapter 1
D. Ruddiman chapters 1 and 2 and Mann chapter 2
Heads up....from the Dean’s office

New course issue.....

• This class fulfills a Natural Science distribution requirement
• It does not count towards Social Science distribution requirement
• Please talk to me after class if you want to know more about this!
Heads up....from me...forgot to mention..

• For each quiz, you can bring into class one sheet of paper with any and all notes on it....you can use both sides...you can try and use the edges...
Party Invite

Free food and good company!

Meet geologists

Learn about geology job prospects

Geology Department
Fall BBQ

Thursday September 5th, 2019
4:00 to 5:00 p.m.

Gather on east-side lawn of Delehanty.

Enjoy delicious grilled food & meet fellow students, faculty and staff.

RSVP to rhopps@uvm.edu by Wed., Sept 4th before 4pm and indicate food allergies or food preferences if any.
What is Climate?

“Climate is what we expect, weather is what we get.”

– Mark Twain

“If you don’t like the weather in New England, just wait a few minutes.”
What is Climate?

“Climate is what we expect, weather is what we get.”

– Mark Twain

• Climate is the statistics of weather

• What kind of weather is expected in Vermont in February?

• What kind of weather is expected in Texas in August?
What is Climate?

Important concept:

- Weather is highly variable, and there is almost always a range of temperatures, precipitation, wind, etc. that can happen on a given day.

- Climate is the expected range of weather for a region at a given time.

- Climate change can only be detected by calculating if this range has changed.

Source: Modified from IPCC, 2007
Overview of Earth’s Climate System

- All of these components affect how energy is distributed around the world
- ...How?
- Where does that energy come from?
Conduction – heat transfer as two surfaces make contact

How Does Energy Move?
How Does Energy Move?

• Conduction – heat transfer as two surfaces make contact

• Convection – heat moves with a fluid
Conduction – heat transfer as two surfaces make contact

Convection – heat moves with a fluid

Radiation – Energy in the form of electromagnetic waves, travels through empty space

The light from the flames is radiation
Electromagnetic radiation

![Image of electromagnetic spectrum]

- **Gamma rays** (0.001 nm, $10^{-12}$ m): More energy
- **X rays**, **Ultraviolet**, **Visible light**, **Infrared**, **Microwaves**, **Radio waves**: Less energy
Where does the energy to power Earth’s Climate System come from?

The Sun!

- Solar radiation provides almost all of the energy for the global climate system
- ...Why does the sun emit so much energy?

(Not to scale)
Why does the sun emit energy??

• Because everything with a temperature above absolute 0 emits radiation!

• Stefan-Boltzmann Law:
  • The warmer an object is, the more radiation it emits and the shorter the radiation’s wavelength
Why does the sun emit energy??

**Stefan-Boltzmann Law**

The warmer an object:

- The more radiation it emits
- The shorter the radiation’s wavelength
Solar Stats (using SB Law):
• Temperature = 6000 K
• Energy Emitted = 3.9 x 10^{26} \text{ W/m}^2
• 150 million km from Earth

Incoming Solar Radiation = 1368 \text{ W/m}^2
How warm should the sun make us?

- In every surface, some fraction of incoming radiation is reflected.
- This fraction (% reflectivity) is called a surface’s ‘albedo’.

![Diagram showing albedo percentages for different surfaces: Water (0%), Forest (20%), Sand (40%), Old snow or ice (60%), Cloud (80%), Fresh snow (100%). The Earth's average albedo is indicated.]
CERES Data Mar 2000 - Feb 2014
Avg Globe: 29.3  NH: 29.3  SH: 29.3  Trop: 23.3
Arc: 51.7  Ant: 68.2  Land: 34.6  Ocean: 27.4 %
How warm should the sun make us?

- Solar constant = 1368 W/m²
- Spread over Earth’s surface = 342 W/m²
- Global albedo mean = ~30%
- So we absorb 70% of 342 = 240 W/m²
• If Earth’s temperature is stable, radiation in = radiation out
  • In = 240 W/m$^2$
  • Out = 240 W/m$^2$
  • $F = \sigma T^4$ (Stefan-Boltzmann Law)
  • 240 = (5.67 x 10^{-8}) x T^4
  • T = 255 K = -18°C = 0°F
  • Actual global mean temp = 288 K = 15°C = 59°F
  • ...What’s wrong here??

average temp = 9°F
Earth has an atmosphere!

Earth’s atmosphere:

- Allows most solar radiation in
- Traps a lot of Earth’s outgoing radiation
- Creates a ~33°C greenhouse effect
- ...again, why?
• Remember, the temperature of a body controls how much radiation it emits and at what wavelengths that radiation is emitted.

• The Earth and the Sun, which have very different temperatures, emit very different radiation spectrums!
Selective radiation absorption in atmosphere

• Gases in Earth’s atmosphere absorb radiation at different wavelengths

• Do not absorb a lot of Sun’s incoming radiation

• When combined, absorb a lot of Earth’s outgoing radiation
Selective radiation absorption in atmosphere

- Gases in Earth’s atmosphere absorb radiation at different wavelengths
- Do not absorb a lot of Sun’s incoming radiation
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Atmospheric Re-Radiation

• A lot of radiation from Earth’s surface gets absorbed in the atmosphere, what happens then?
• Atmospheric gases radiate more, sending off radiation in all directions
• Roughly half gets directed back down to Earth
• Earth is essentially being heated from two sources, the sun and the atmosphere
John Tyndall was an Irish physicist who proved the connection between atmospheric carbon dioxide and the greenhouse effect in 1859!! He was also an accomplished mountaineer and glaciologist, leading one of the first teams to reach the top of the Matterhorn (1868). His work paved the way for much of our modern understanding of atmospheric physics.
Global Temperature ‘Knobs’

- Solar Output
- Albedo
- Greenhouse Effect
What are we (humans) doing to each ‘knob’?

- **Solar Output**: No Impact
- **Albedo**: Lowering (melting ice)
- **Greenhouse Effect**: Increasing!
Next week: Fundamentals of atmospheric circulation

- How does moving air distribute energy?
- How has atmospheric circulation shaped the modern climate system?

**Learning Objectives**

1. Explain why air moves in predictable patterns across the globe
2. Explain how atmospheric circulation results in the observed global distribution of climates
3. Identify dry or wet regions on Earth based on the characteristics of air movement and pressure in those areas
Assignments for Next Week

• Ruddiman Ch. 1, Mann Ch. 2 (and reading due for this week!)

• First quiz (practice, testing clickers and learning our question) on Tuesday during class