"What do you recommend for greenhouse gas?"

Class 2: Class Information & Global Energy Balance

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

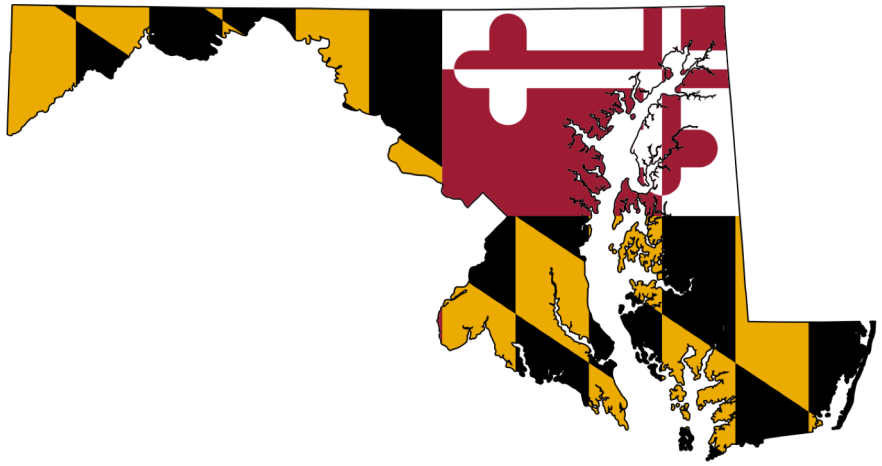
Learning Objectives

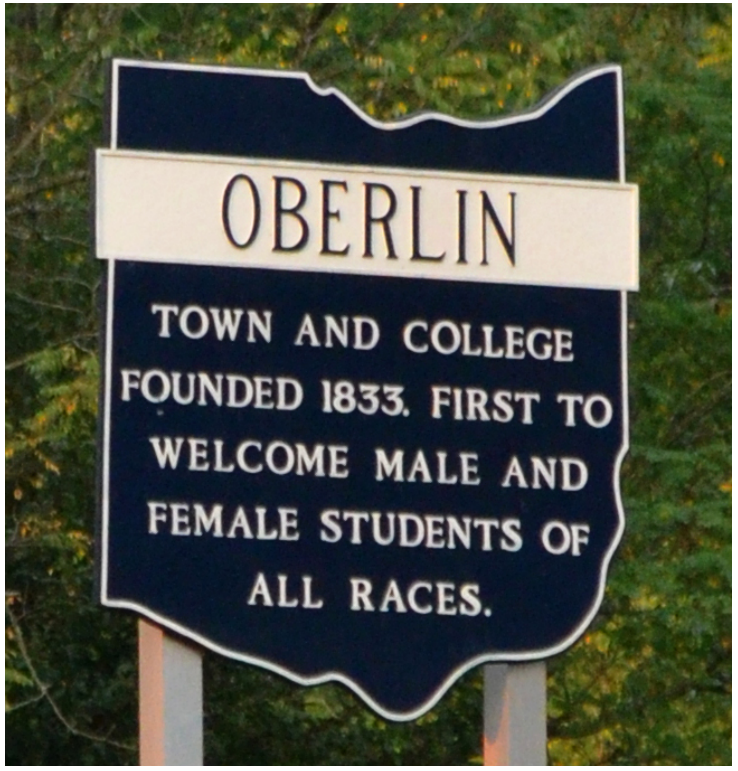
1. List the ways in which energy enters and leaves the Earth
2. Identify the three primary controls on global average temperature, explain how they work
3. Explain why a simple calculation of Earth's equilibrium temperature using data on solar energy does not equal Earth's actual average temperature
4. Identify the fallacy underlying claims that increasing atmospheric CO_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!




OBERLIN
TOWN AND COLLEGE
FOUNDED 1833. FIRST TO
WELCOME MALE AND
FEMALE STUDENTS OF
ALL RACES.


EV-102
8/19/2018


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.

BOSTON COLLEGE

BATES

Christopher Halsted, M.S.

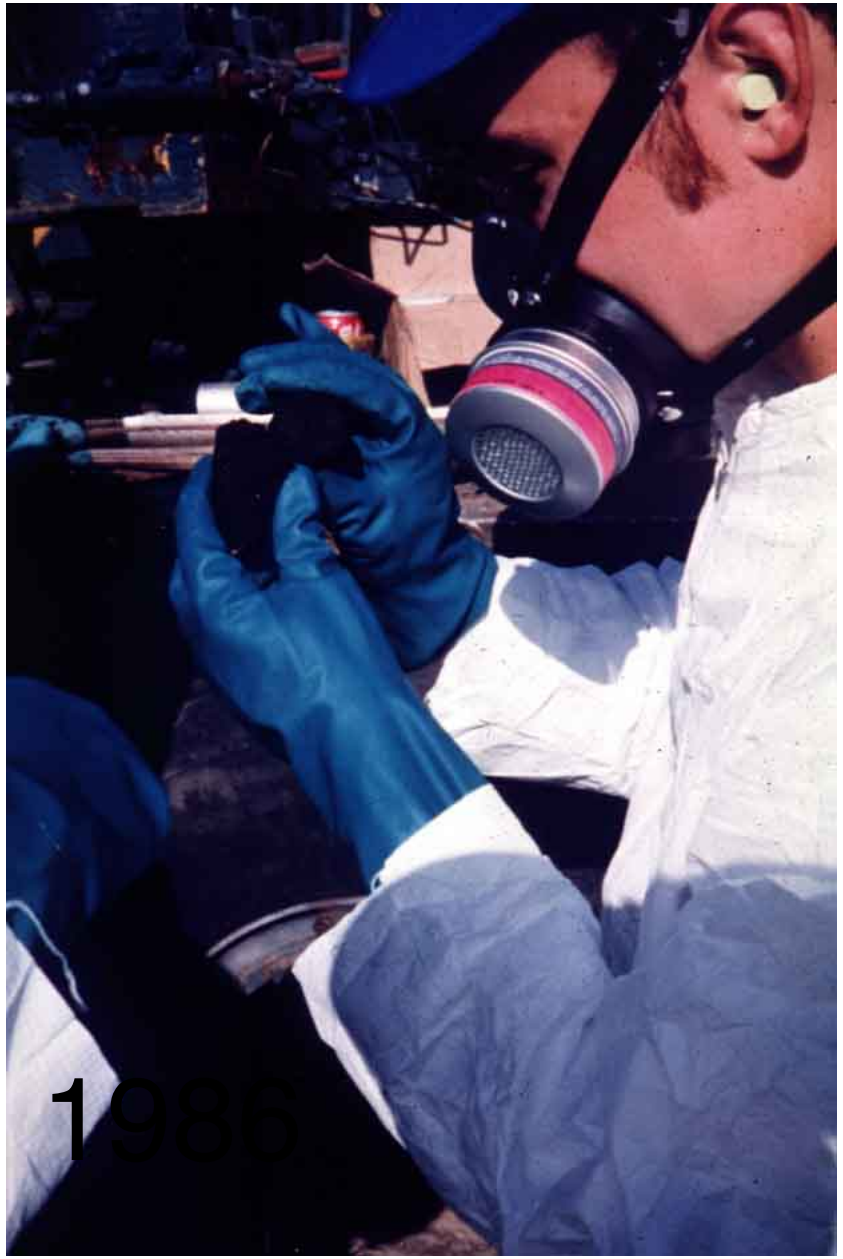
Christopher Halsted, M.S.

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

UNUSUAL SCIENCE that matters to people

COLD WEATHER (Climate) SCIENCE

www.uvm.edu/landscape

You searched for: **snow, roller**. Here are the results:

Refine Search | Distribution | Image Details | List | Thumbnails

Now Showing Image 3 of 10

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 2006-12-11: 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 is 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.

Alaska Dispatch News

NEWS POLITICS VOICES ARCTIC CULTURE SPORTS ADVENTURE MULTIMEDIA

Sports

Biathletes battle wind, diminishing snow at Kincaid Park

Beth Bragg | December 29, 2015

Email Print Like 38 Twee G+1 2 Text Size

PLAY

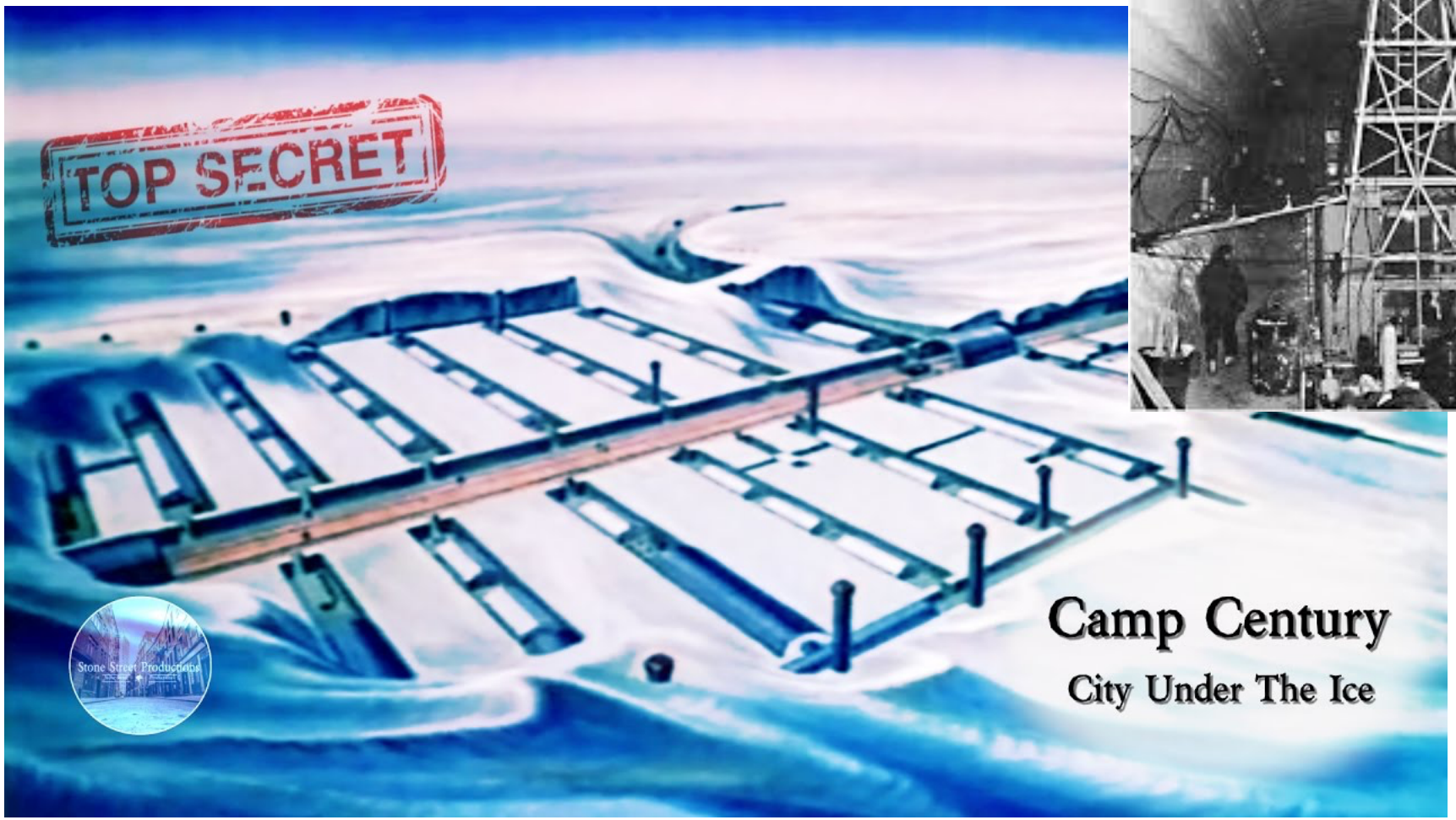
Photos: Youth and Junior Biathlon World Team Trials

Marika Massey-Bierman of Craftsbury Nordic of Vermont skis to 5th place in the Youth Women 10K Pursuit event at the USA Youth and Junior Biathlon World Team Trials on Tuesday, December 29, 2015, at Kincaid Park.

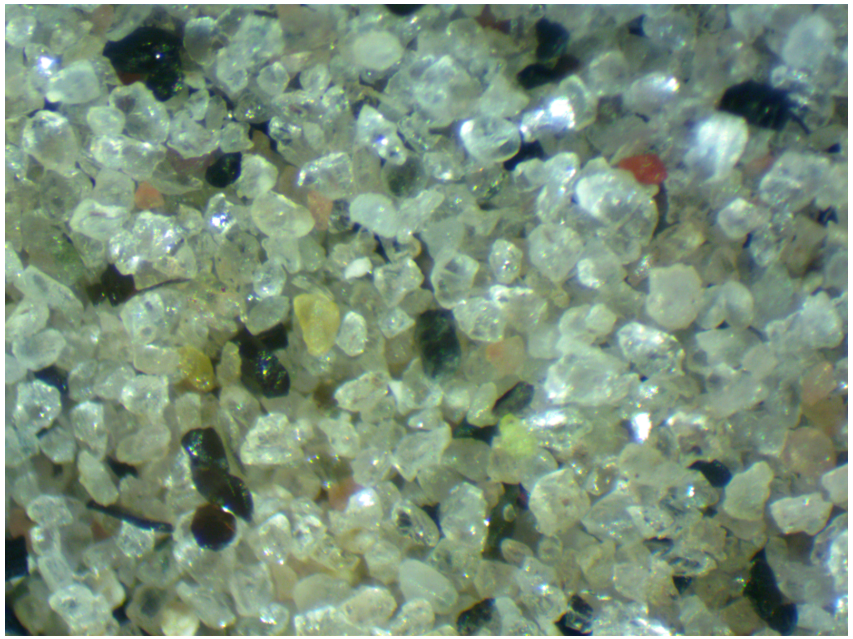
Erik Hill / ADN

Marika Massey-Bierman
December 13, 1999

Quincy Luna Massey-Bierman
March 6, 2003


TOP SECRET
Stone Street Productions
Camp Century
City Under The Ice

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

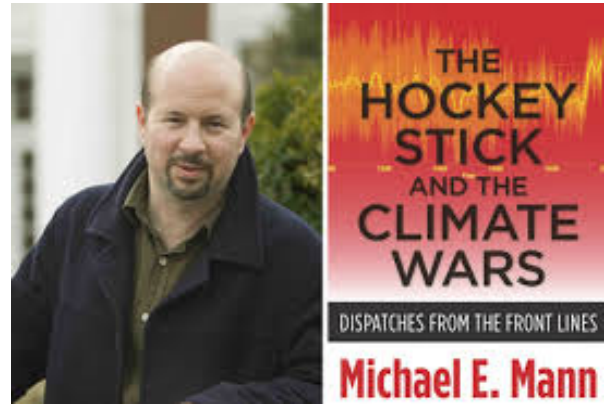
Which one of the teaching staff has never sampled glacial boulders to understand climate change?

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

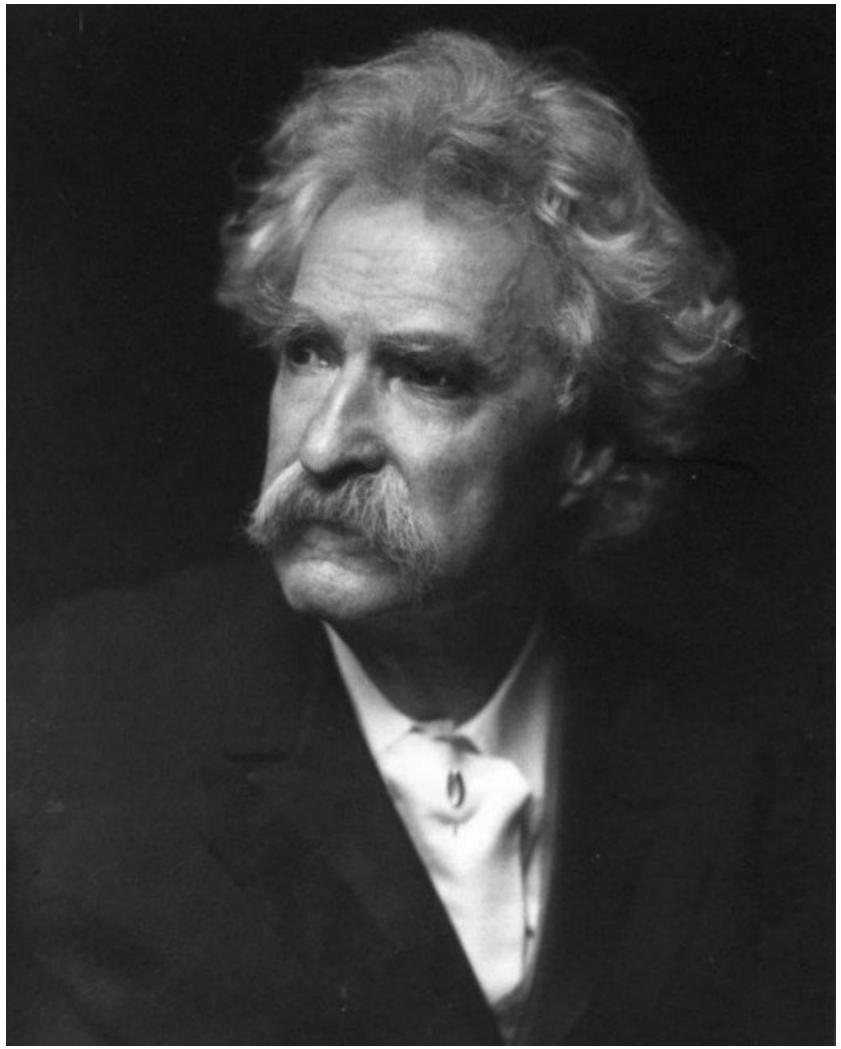
Thursday September 5th, 2019
4:00 to 5:00 p.m.

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?

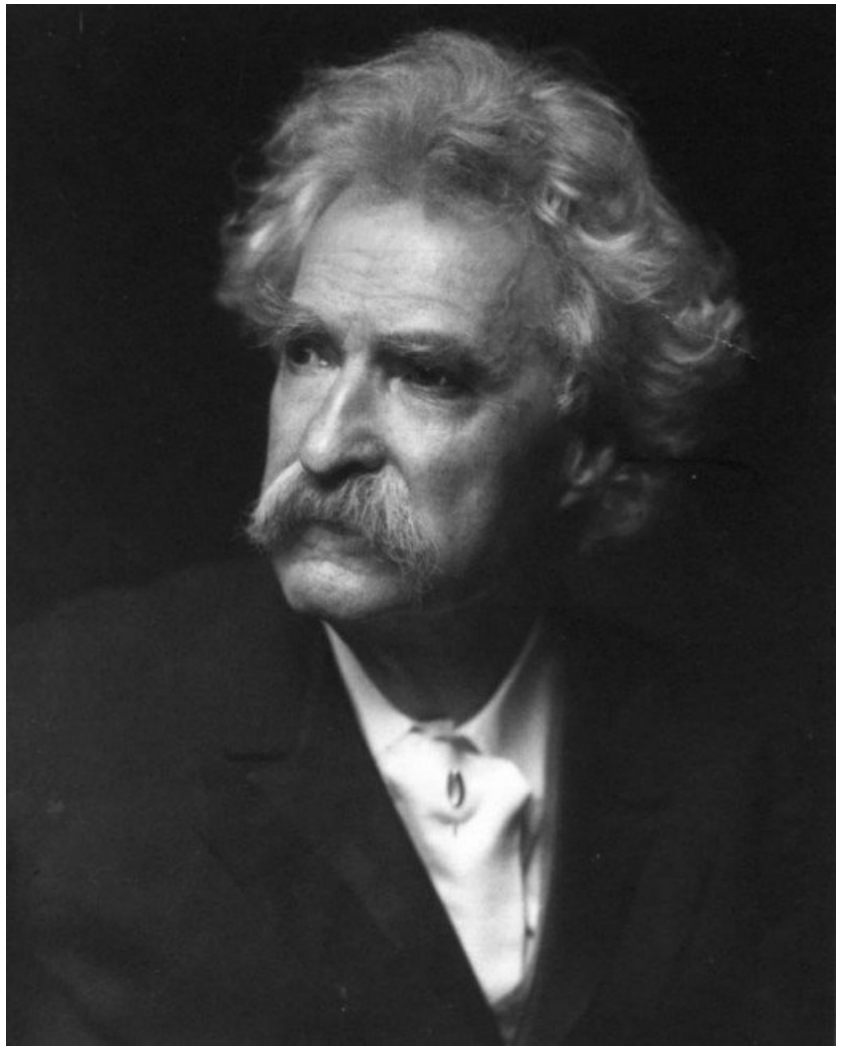


"Climate is what we expect, weather is what we get."

– Mark Twain

"If you don't like the weather in New England, just wait a few minutes."

What is Climate?

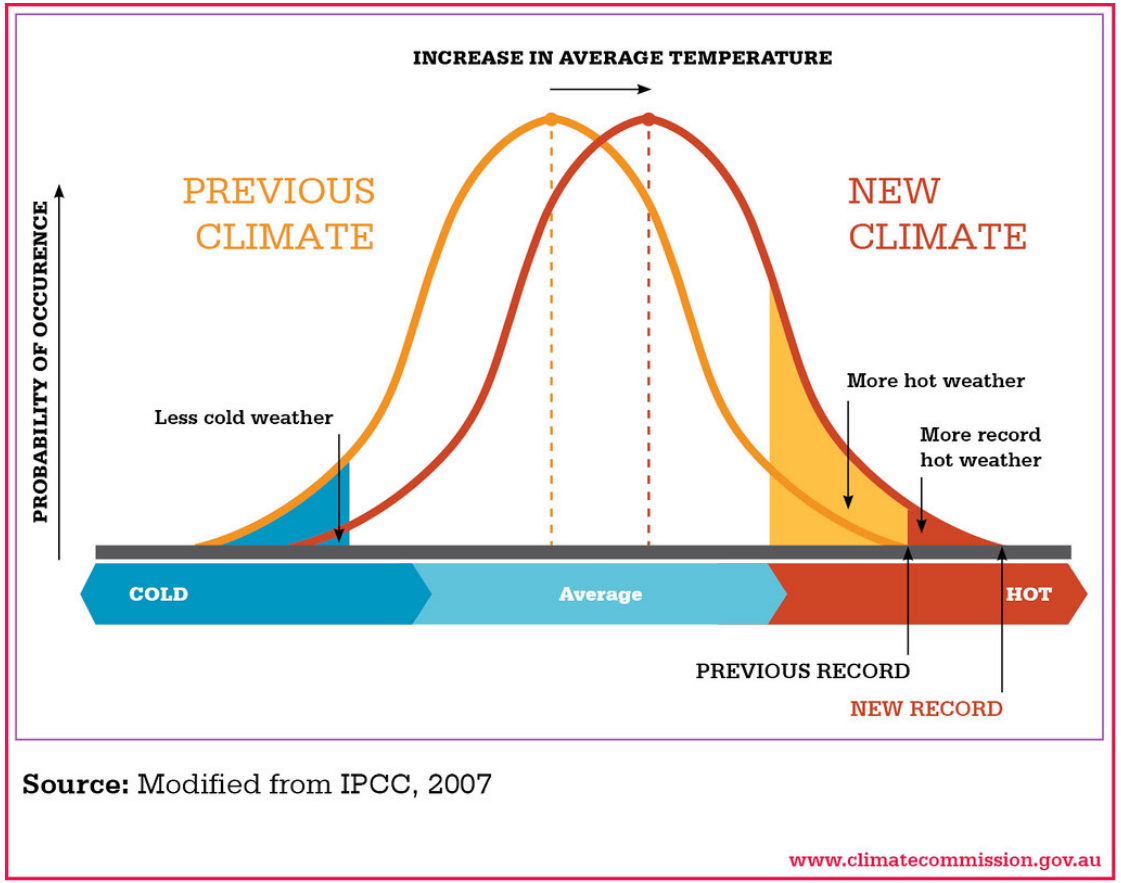


"Climate is what we expect, weather is what we get."

– 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?

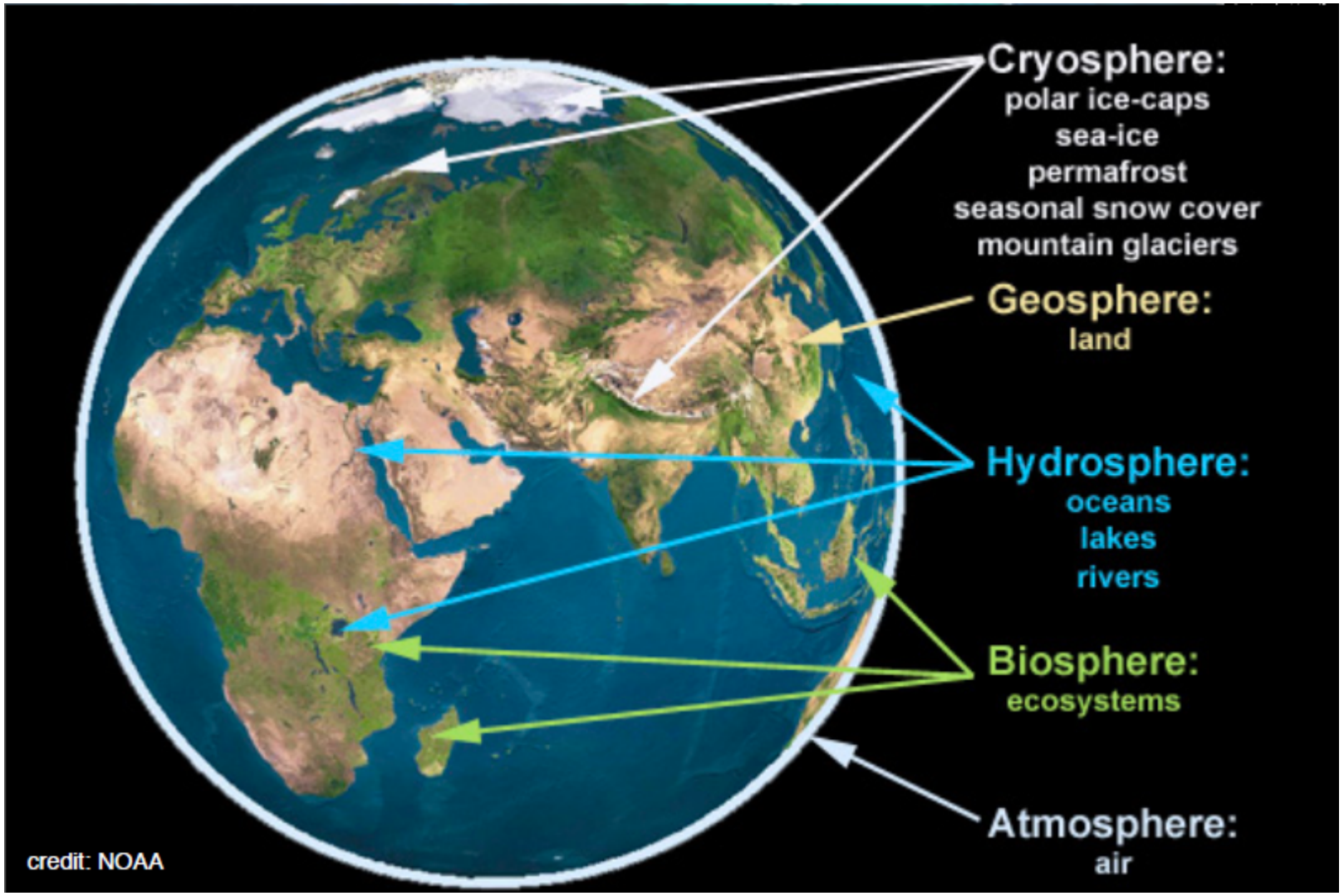
What is Climate?



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

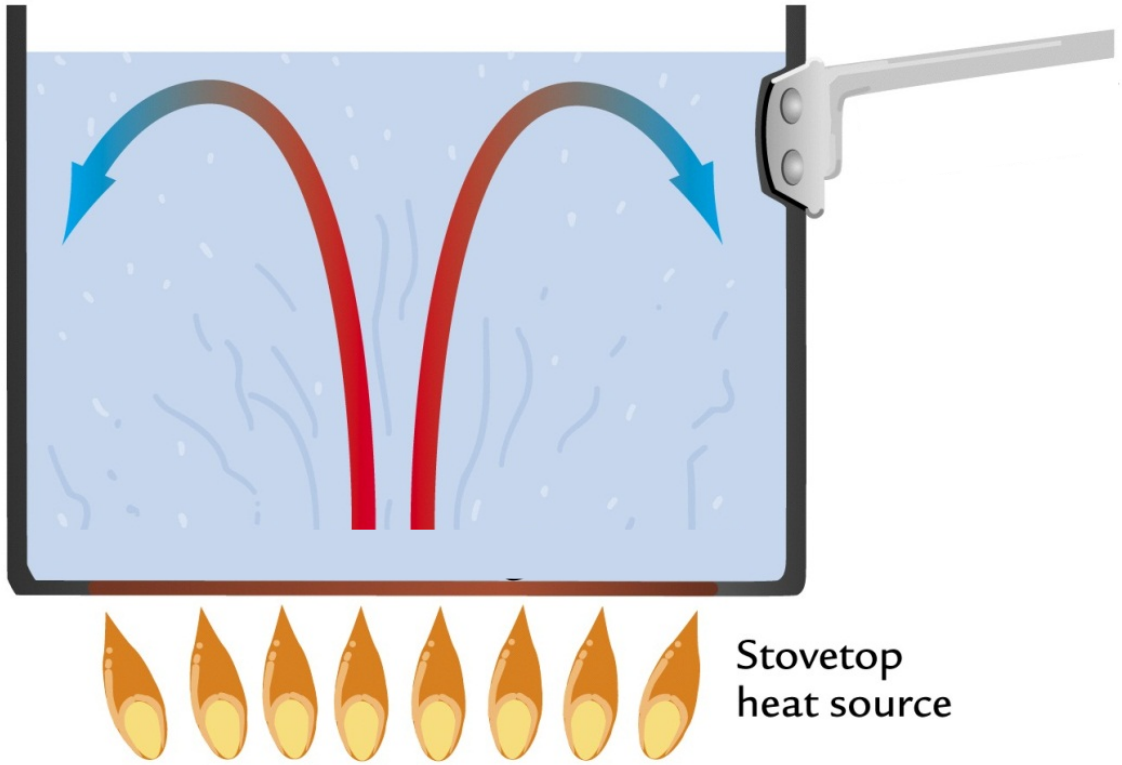
Overview of Earth's Climate System



- All of these components affect how energy is distributed around the world
- …How?
- Where does that energy come from?

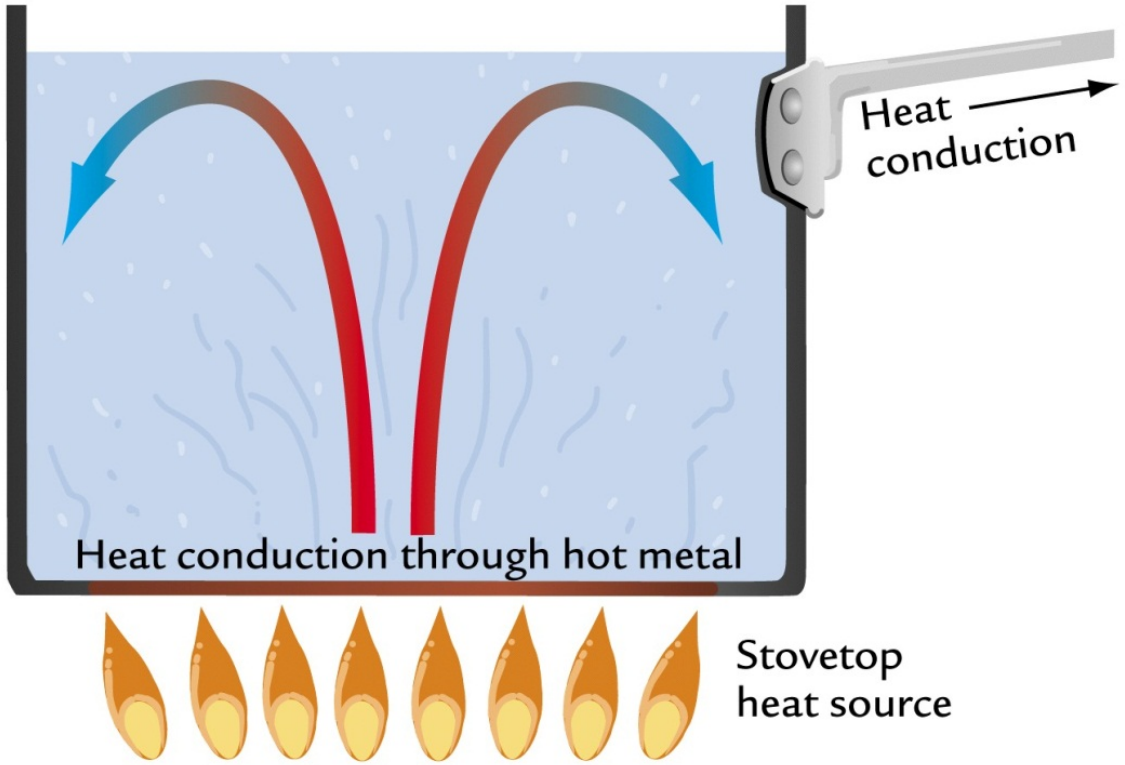
How Does Energy Move?

- Conduction – heat transfer as two surfaces make contact



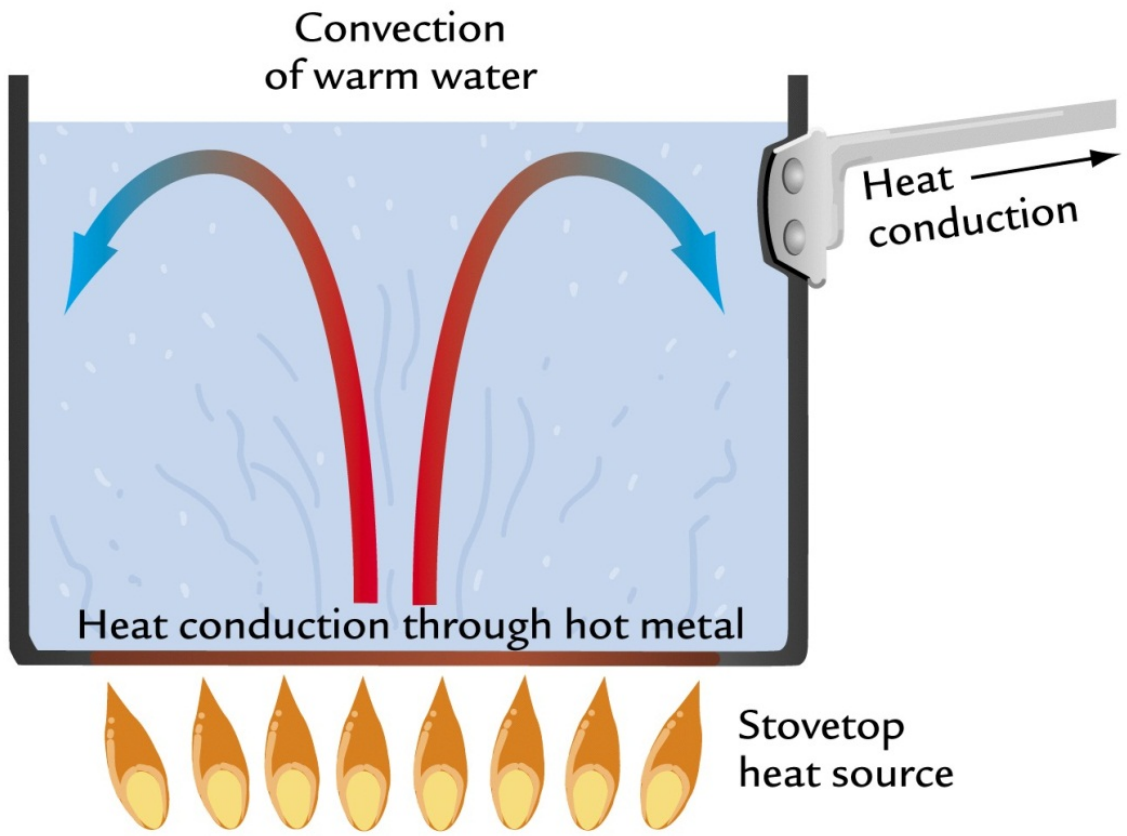
How Does Energy Move?

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



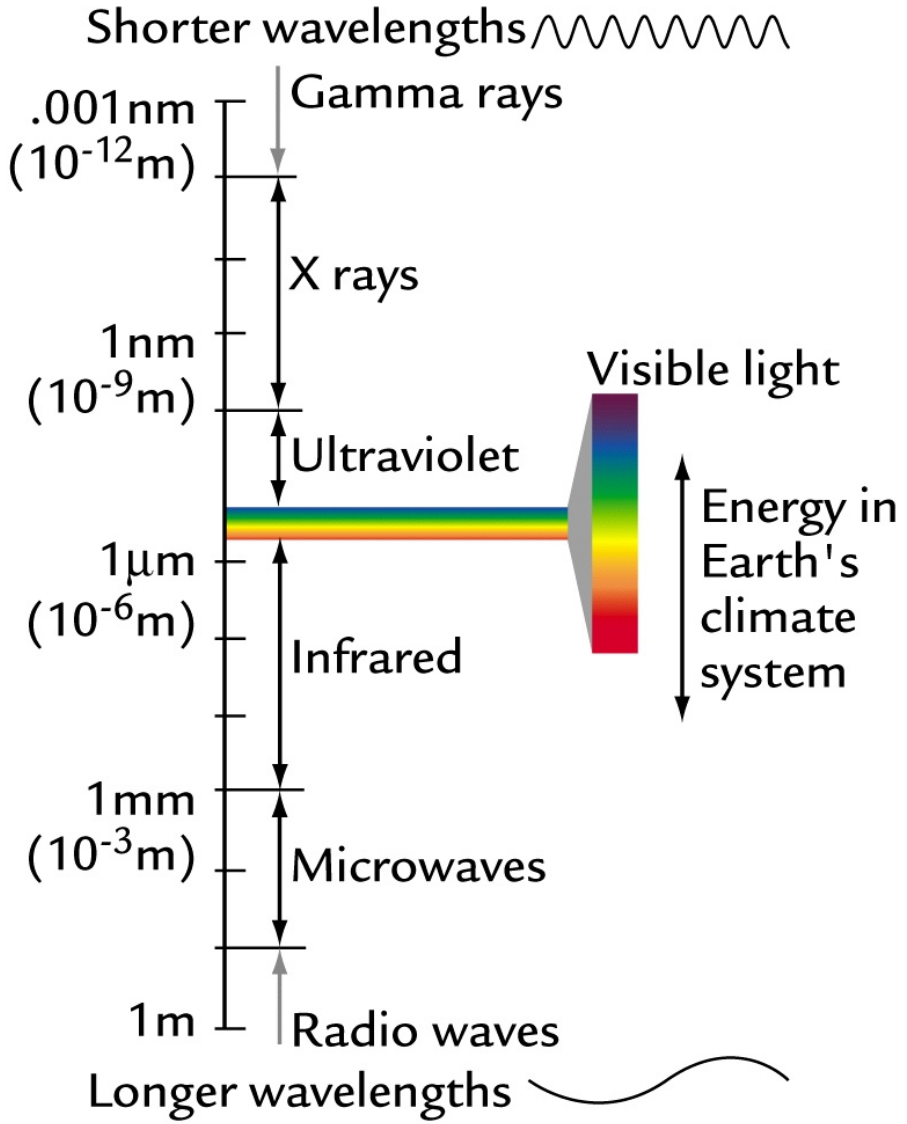
How Does Energy Move?

- 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



More Energy

Less Energy

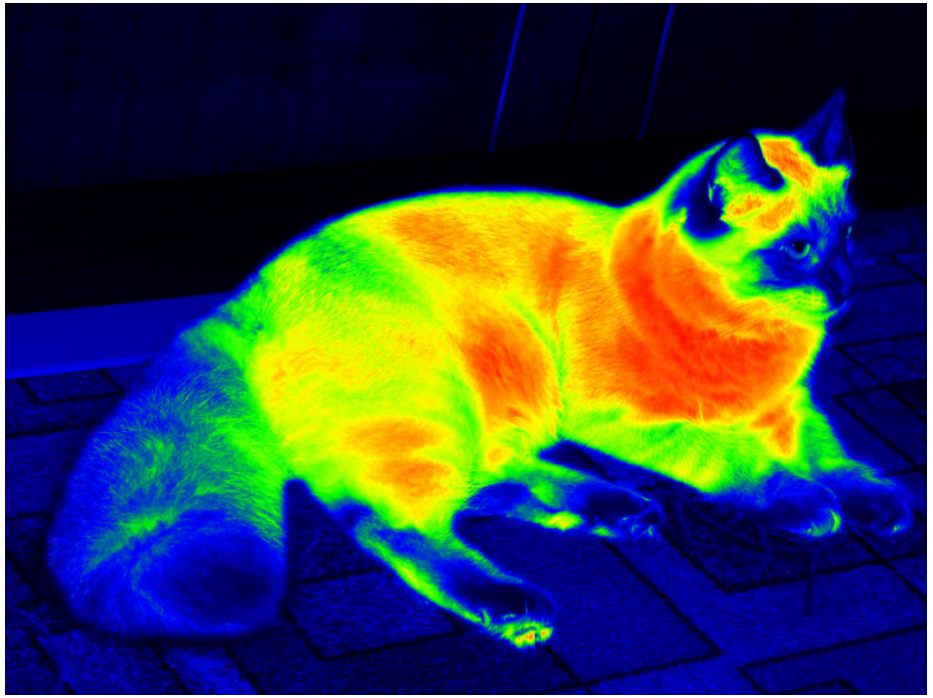
Where does the energy to power Earth's Climate System come from?

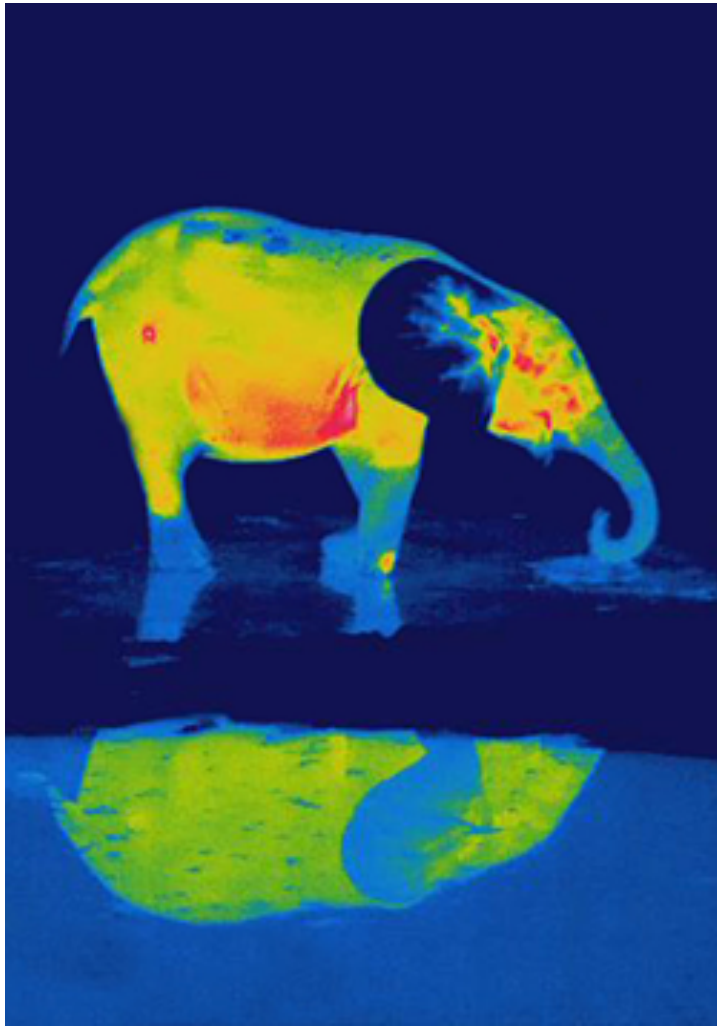
The Sun!

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

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
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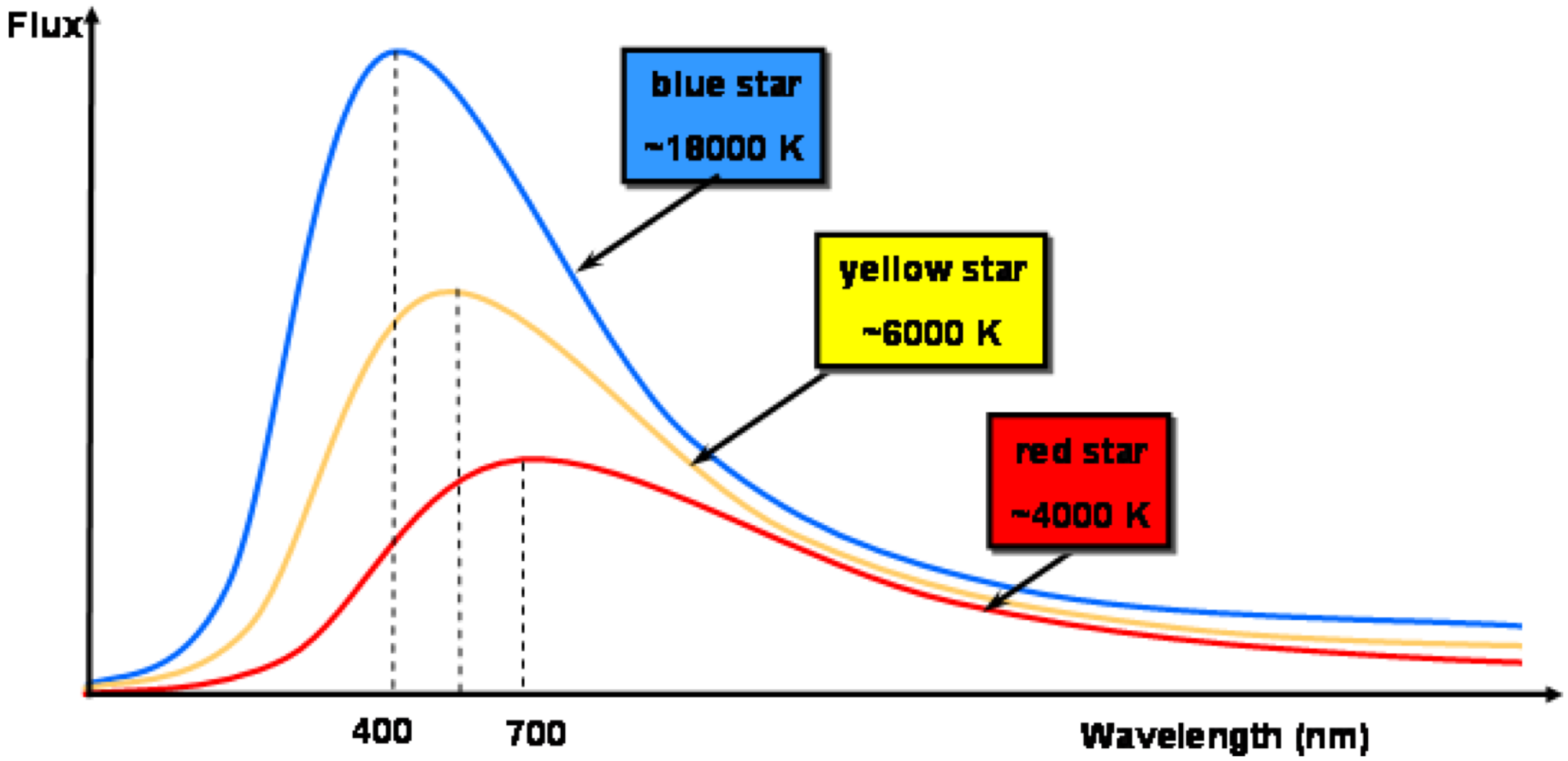
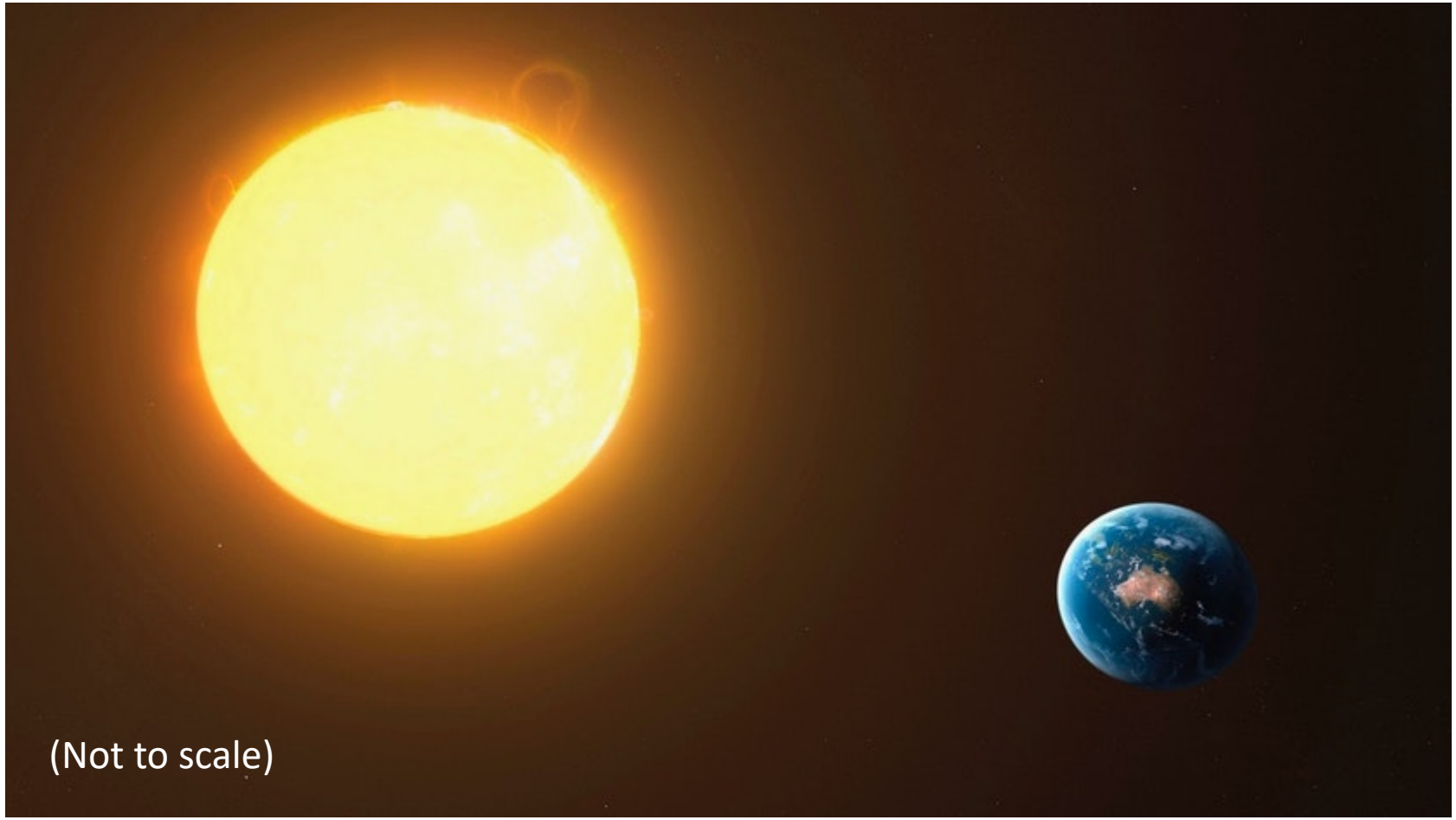


How Much Energy Does the Sun Emit?

Solar Stats (using SB Law):

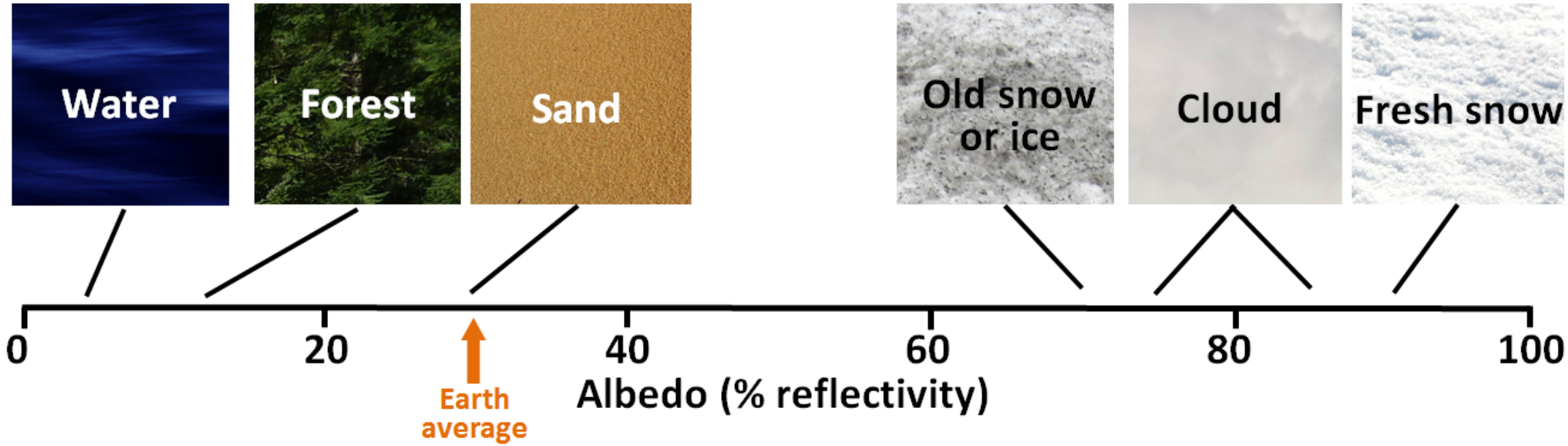
- Temperature = 6000 K
- Energy Emitted = 3.9 x 10^{26} W/m^2
- 150 million km from Earth

Incoming Solar Radiation = 1368 W/m^2



How warm should the sun make us?

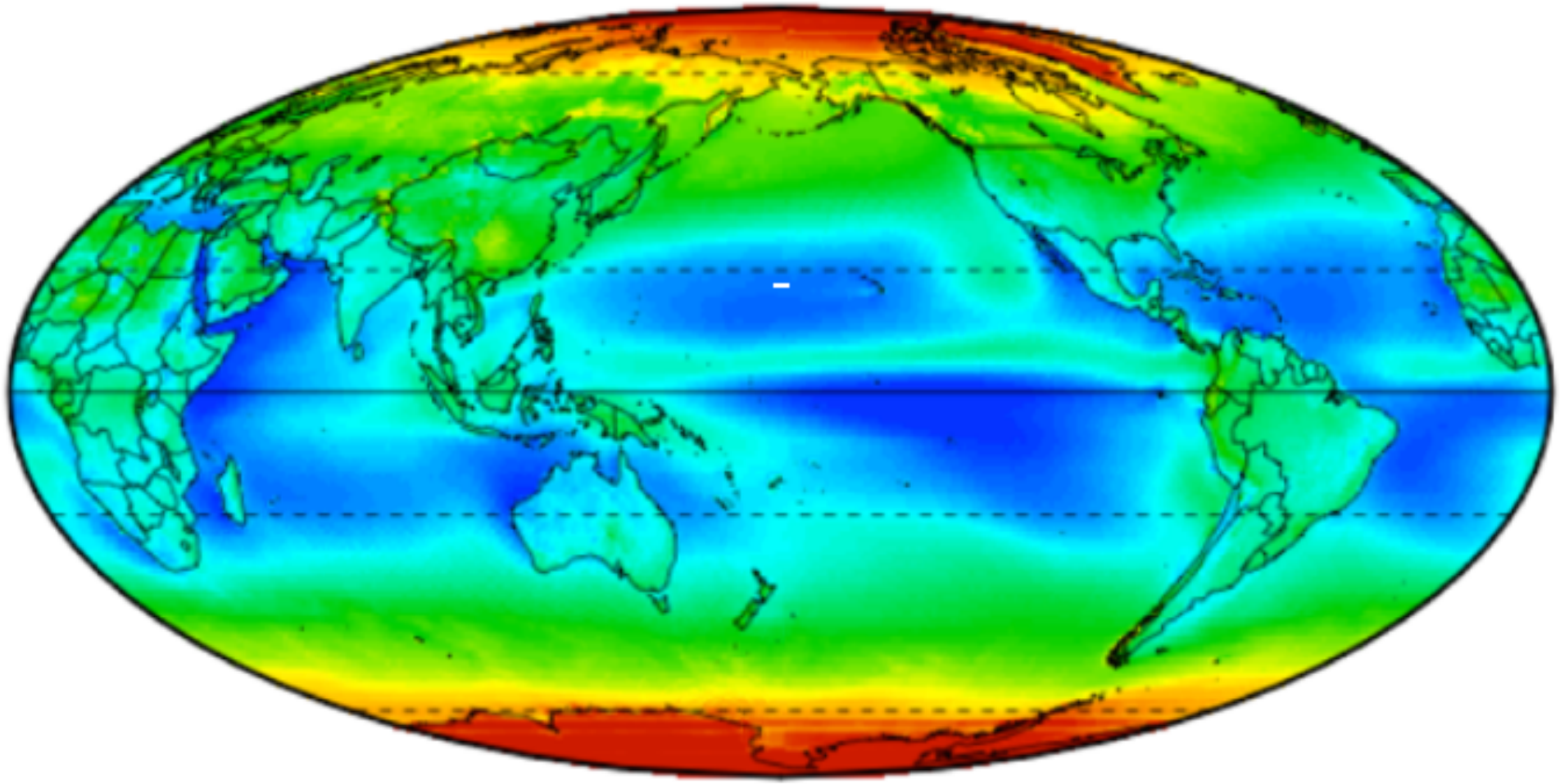
- In every surface, some fraction of incoming radiation is reflected
- This fraction (% reflectivity) is called a surface's 'albedo'



CERES Data Mar 2000 - Feb 2014

Avg Globe: 29.3 NH: 29.3 SH: 29.3 Trop: 23.3

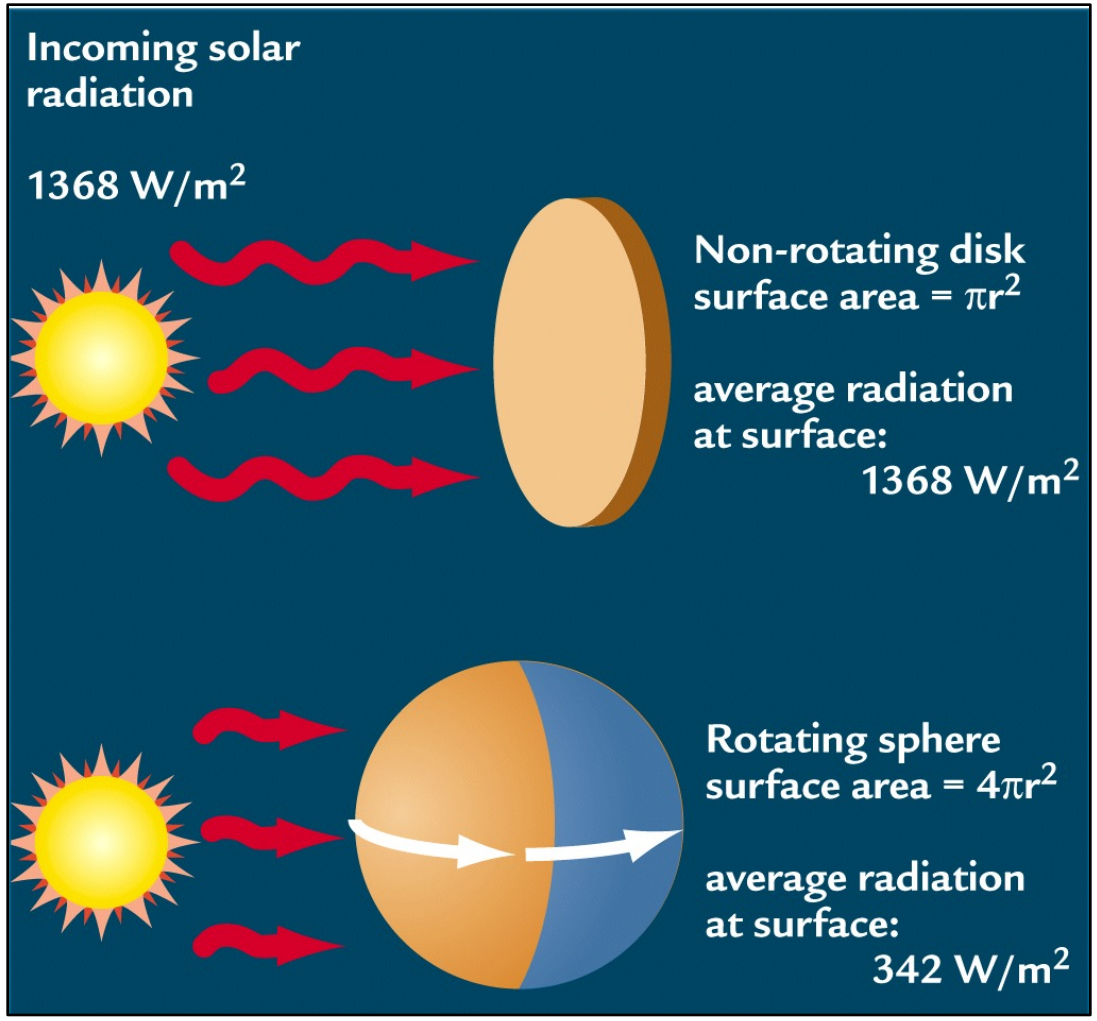
Arc: 51.7 Ant: 68.2 Land: 34.6 Ocean: 27.4 %



12 % 25 % 38 % 51 % 64 % 77 %

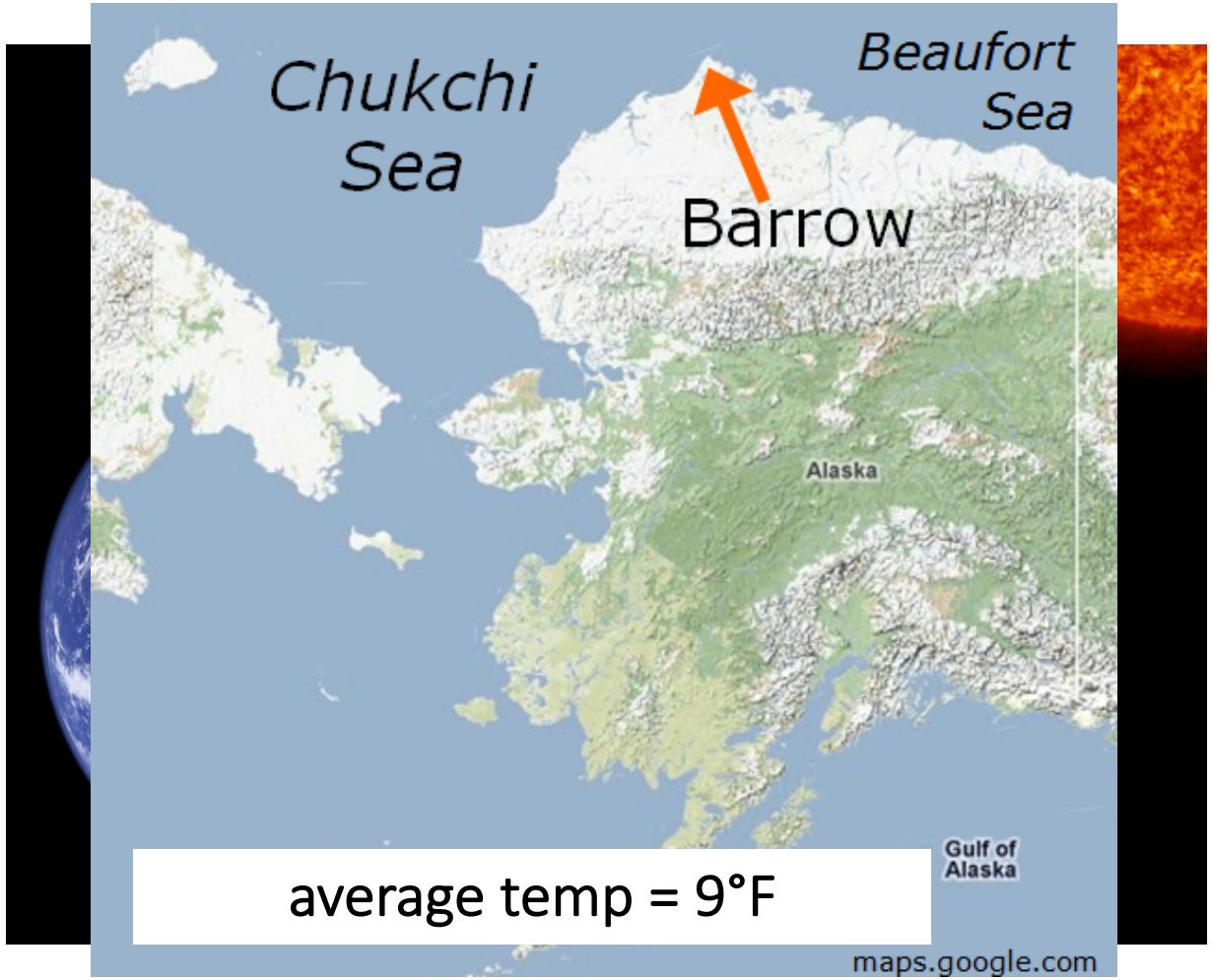
How warm should the sun make us?

- Solar constant = 1368 W/m^2
- Spread over Earth's surface = 342 W/m^2
- Global albedo mean = ~30%
- So we absorb 70% of 342 = **240 W/m^2**



How warm should the sun make us?

- 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)
  - $240 = (5.67 \times 10^{-8}) \times T^4$
  - $T = 255\ K = -18°C = 0°F$
  - Actual global mean temp = 288 K = 15°C = 59°F
  - …What's wrong here??



Earth has an atmosphere!

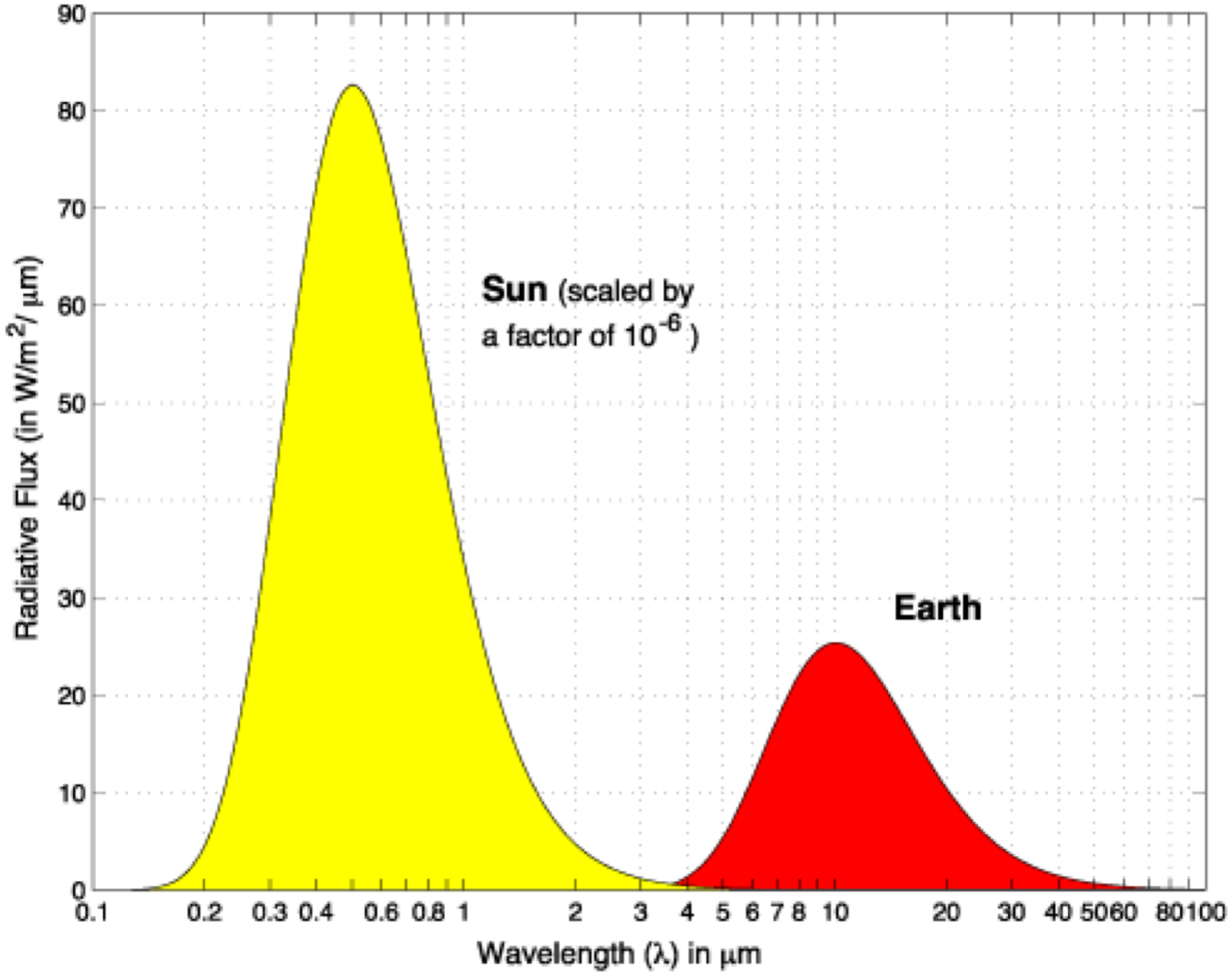
Earth's atmosphere:

- Allows most solar radiation in
- Traps a lot of Earth's outgoing radiation
- Creates a ~33°C greenhouse effect

- …again, why?

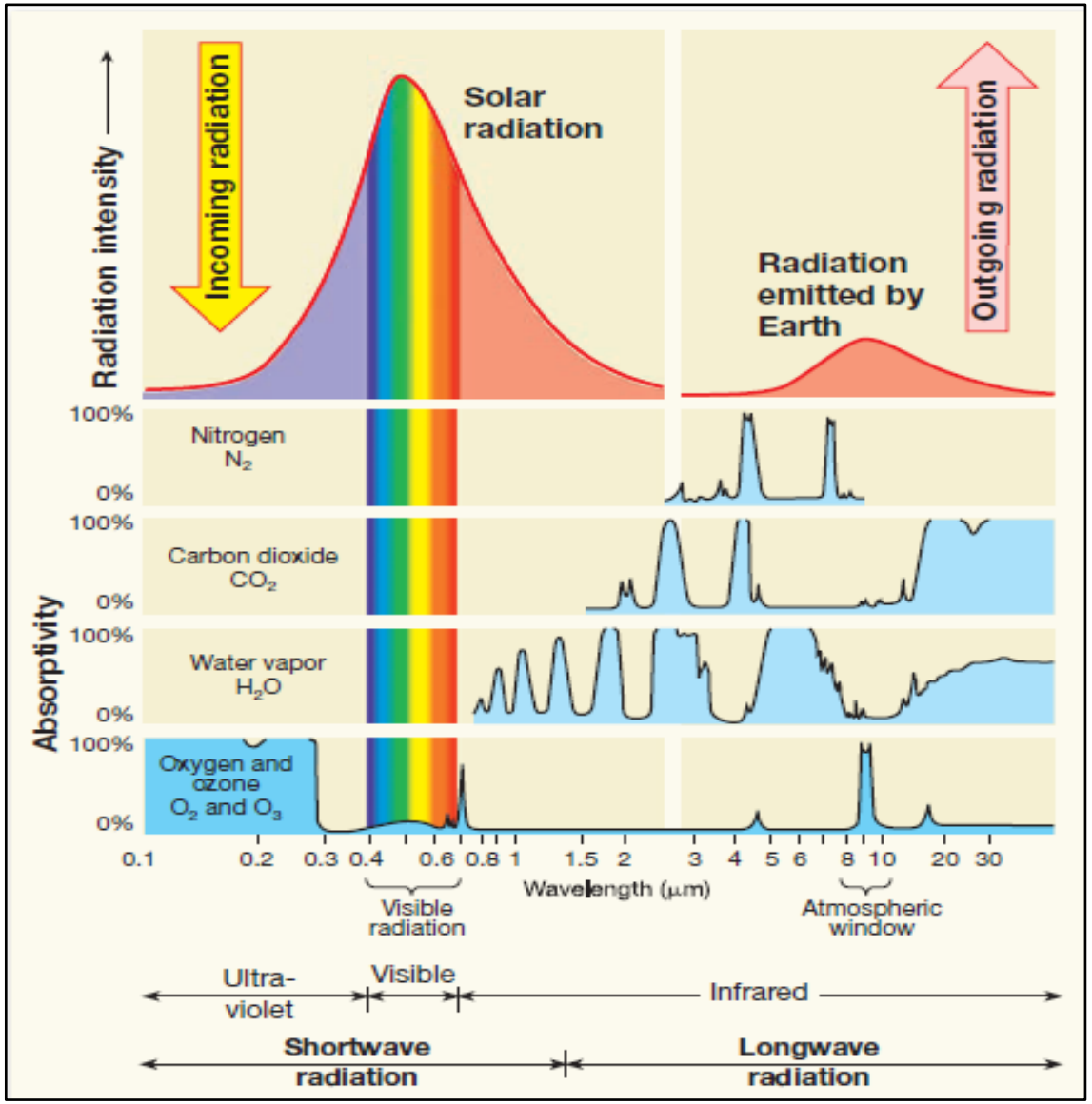
Solar vs. Earth Energy Spectrum

- 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



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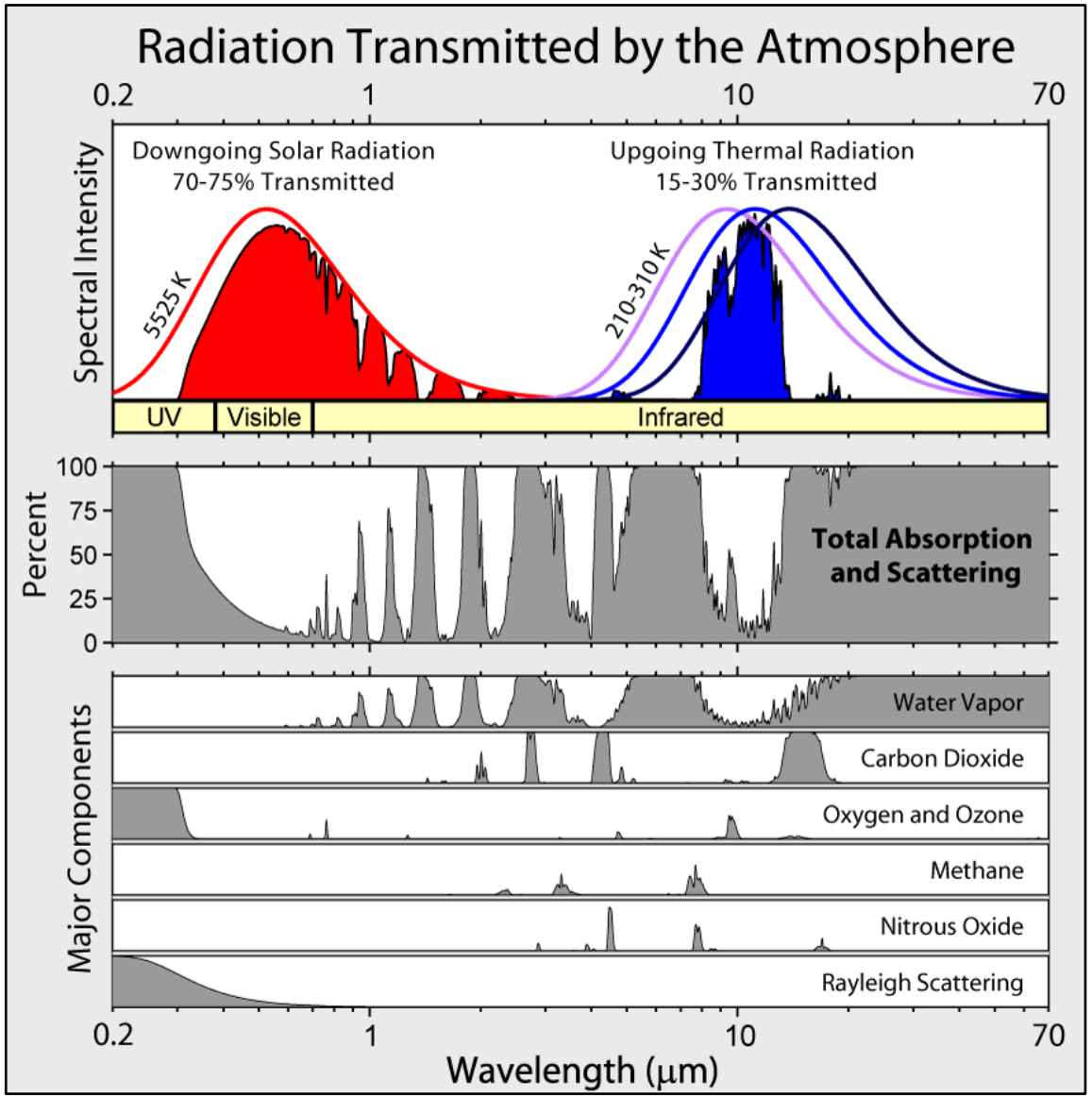
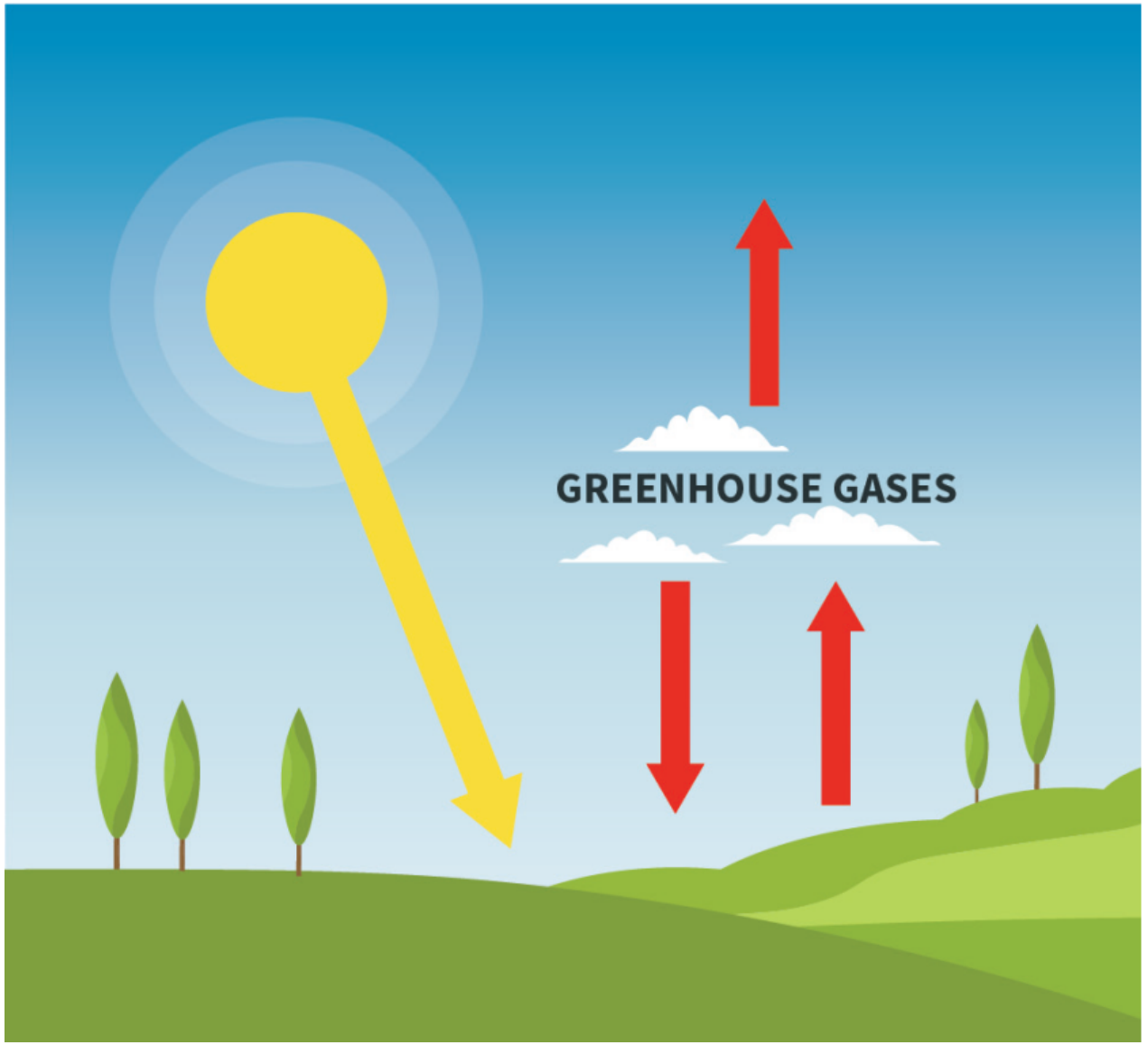
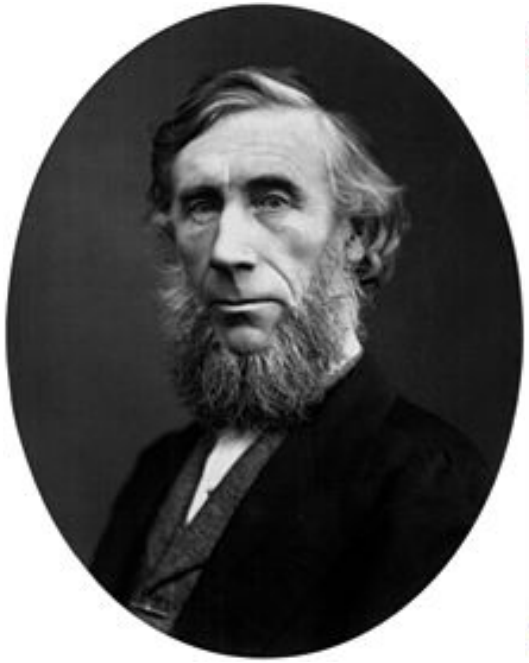


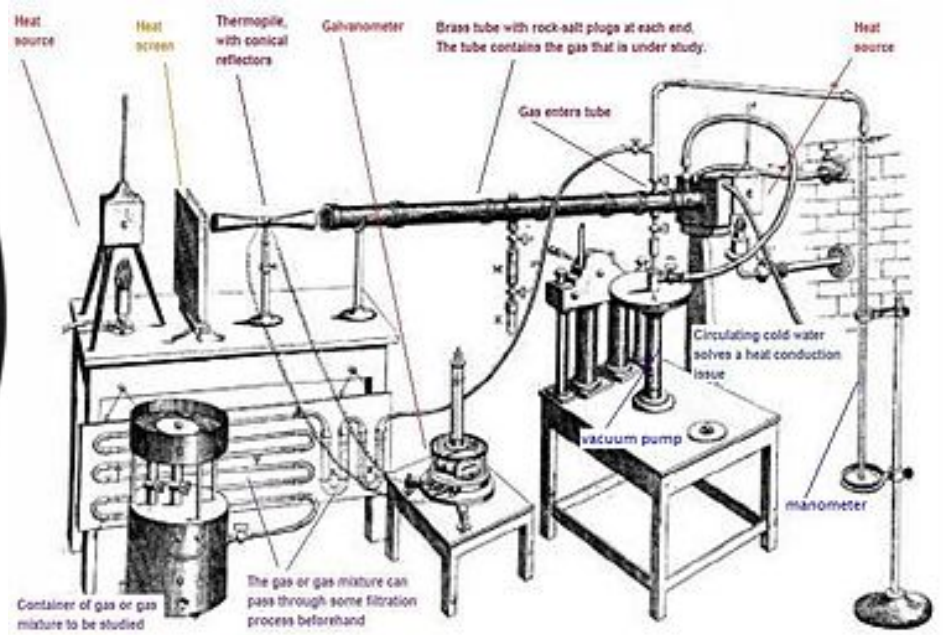
Atmospheric Re-Radiation

- 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 (1820 – 1893)

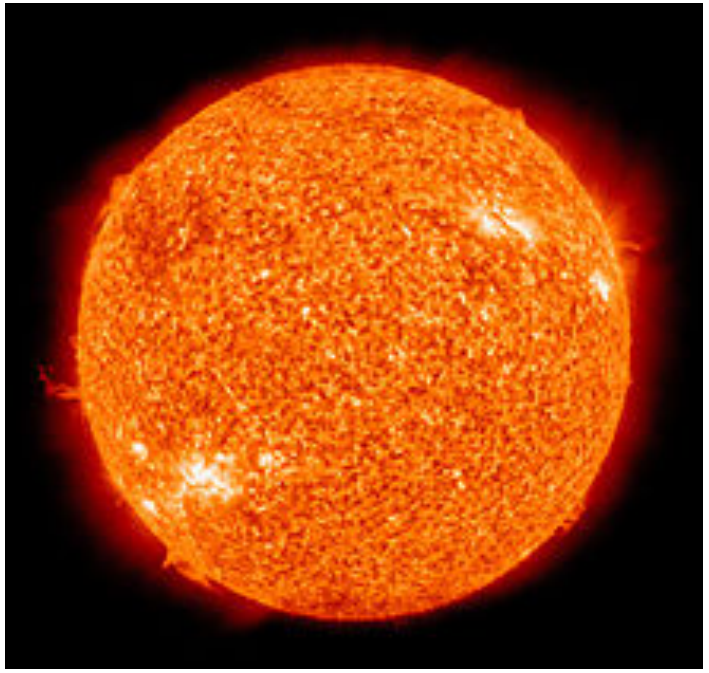




John Tyndall was an Irish physicist who proved the connection between atmospheric carbon dioxide and the greenhouse effect in *1859*!! He was also an accomplished mountaineer and glaciologist, leading one of the first teams to reach the top of the Matterhorn (1868). His work paved the way for much of our modern understanding of atmospheric physics.

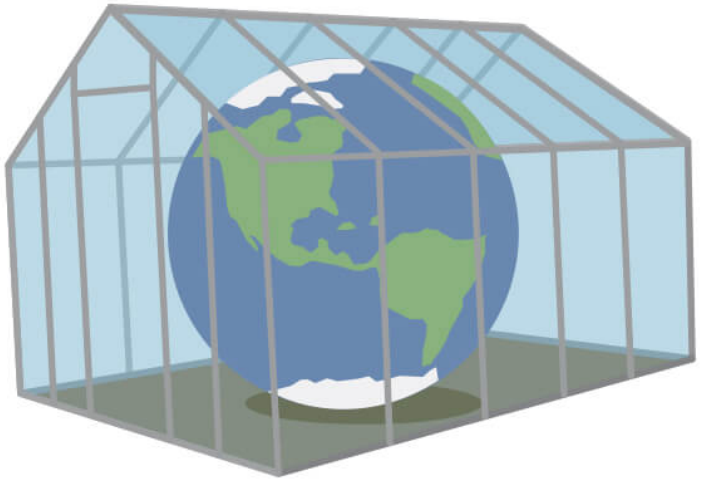
Global Temperature ‘Knobs’

Solar Output



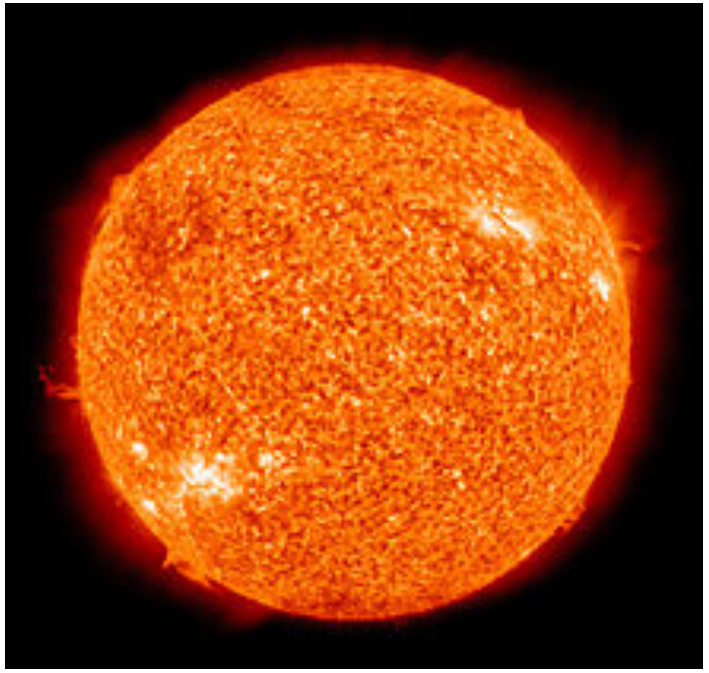
Albedo

Greenhouse Effect



What are we (humans) doing to each ‘knob’?

Solar Output

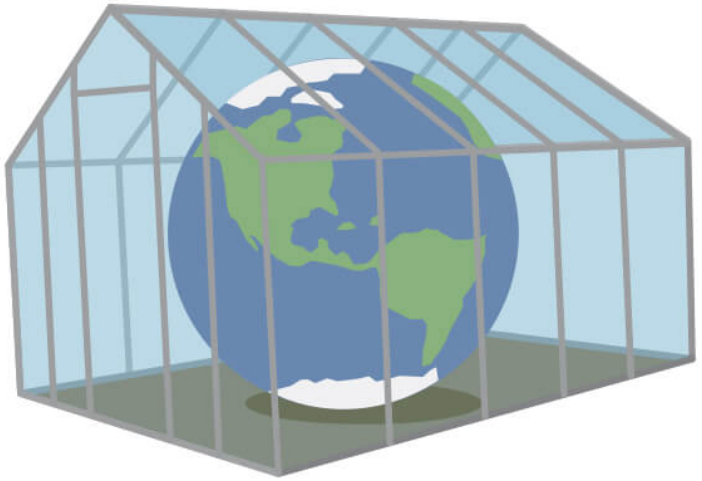


No Impact

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