

Climate Change Learning Module Study Guide



Learning Module Location: <http://www.meted.ucar.edu/broadcastmet/climate/>

The first several ideas are not specifically in the learning module but provide relevant information to climate change science.

Isotopes of atoms are distinguished by the total number of neutrons and protons in the nucleus. For example, all carbon atoms have 6 protons in the nucleus. Some also have 6 neutrons, some 7, and some 8 neutrons in the nucleus corresponding to the isotopes ^{12}C , ^{13}C , and ^{14}C . The analysis of the isotopic abundance of ^{13}C to ^{12}C in the atmosphere has been used to estimate the human fingerprint of carbon emissions.

All Oxygen atoms have 8 protons in the nucleus. See [Oxygen isotopes](#) for more information. Some also have 8 neutrons and some 10 neutrons in the nucleus corresponding to the isotopes ^{16}O and ^{18}O . The analysis of the isotopic abundance of ^{18}O to ^{16}O in ocean sediments or ice cores can be used as a proxy for temperature of the past. The idea is that water (H_2O) with ^{18}O in it evaporates from the ocean water more slowly than water with ^{16}O in it. This differential evaporation rate depends on temperature.

When $^{18}\text{O}/^{16}\text{O}$ ratio in ocean sediments is higher than normal this implies colder temperatures. Since ice cores form essentially from atmospheric water vapor, higher $^{18}\text{O}/^{16}\text{O}$ ratio in ice cores implies warmer temperatures.

[NASA temps](#): In the Climate Change learning module the latest data discussed is 2008. [NASA temps](#) provides most recent data. Most climate scientists believe that some of the warming seen in the early 20th century (1900-1950) was from increased solar brightness and that most of the warming that we've seen since 1950 is from anthropogenic activity (fossil fuel combustion and land use changes or deforestation).

Paleoclimatology is the study of past climates using such things as ice core samples, tree rings (dendrochronology), pollen samples, ocean sediments, and fossils.

Study guide for Learning Module Starts here:

Svante Arrhenius ~1900 was first to propose that humans could alter Earth's climate by adding carbon dioxide to the atmosphere. He estimated that doubling atmospheric carbon could raise Earth's mean temperature by 9°F to 11°F. In 1908 he estimated that this could take centuries.

What changes climate?

Natural factors

Sun got brighter between 1750-1950 by about 0.1 % resulting in an estimated warming of about 0.2 °F in the early 20th century. The sun has not gotten brighter since direct observations of the sun by satellites began in 1979.

Milankovitch cycles linked with ice ages take thousands of years. Milankovitch cycles important in explaining variations in climate over the past million years.

plate tectonics (drifting continents)

snow and ice reflect sunlight. More snow and ice implies less solar energy absorbed by Earth resulting in a cooler earth.

Volcanic eruptions

Ocean circulation

Natural greenhouse gases

Greenhouse effect

water vapor is most important

Satellites have detected an increase in water vapor over the oceans since 1988.

Emission rate, lifetime, and effectiveness of each molecule at trapping long wave radiation all determine the importance of a particular greenhouse gas to anthropogenic climate change.

Carbon Cycle

An important process for permanently removing CO₂ from the atmosphere is by weathering of rocks. CO₂ is dissolved in rain water to make a weak carbonic acid. This combines with the minerals of rocks and is washed into the ocean. Sea organisms incorporate this carbon into their shells and when they die the carbon (in the form of calcium carbonate) settles to the ocean floor. There it is gradually pulled down into Earth's interior via plate tectonics and later (~100 Millions year) released back into the atmosphere by volcanoes.

By burning oil, coal, and natural gas we effectively release carbon into the atmosphere that took 100s of millions of years to store.

Past Climate

How does the present atmospheric CO₂ concentration compare to records of the past 800 thousand years?

Earth's Climate History

Little ice age 550--220 yrs ago weaker sun, increased volcanic activity

Medieval warm 1100 to 650 years ago temperatures were close to what they were 50 years ago.

Is it Real?

Evidence of Change

Temperatures.

2008 temperatures were lower than 2000 to 2007 annual temperatures. This was likely a result of a strong La Nina event in the equatorial Pacific. How about most recent years? [NASA Temps](#)

Warming stronger over land than over oceans (this observation is in agreement with model projections)

Warming is stronger in the higher latitudes than in the tropics. (this observation is in agreement with model projections)

Oddly enough, although the surface temperatures are expected to warm from additional greenhouse gases, stratospheric temperatures are expected to cool. This has implications related to understanding future stratospheric ozone changes.

Oceans.

Global average sea levels have risen by about 4 to 10 inches in the 20th century from melting ice and snow and thermal expansion of ocean water (ocean water expands when it gets warmer).

Oceans are 30% less alkaline (more acidic) than they were 100 years ago.

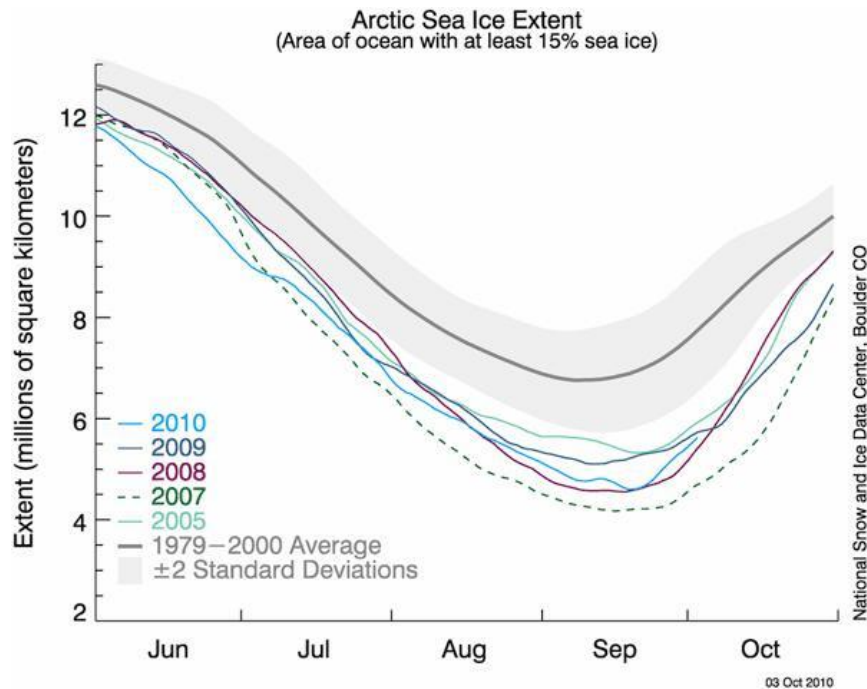
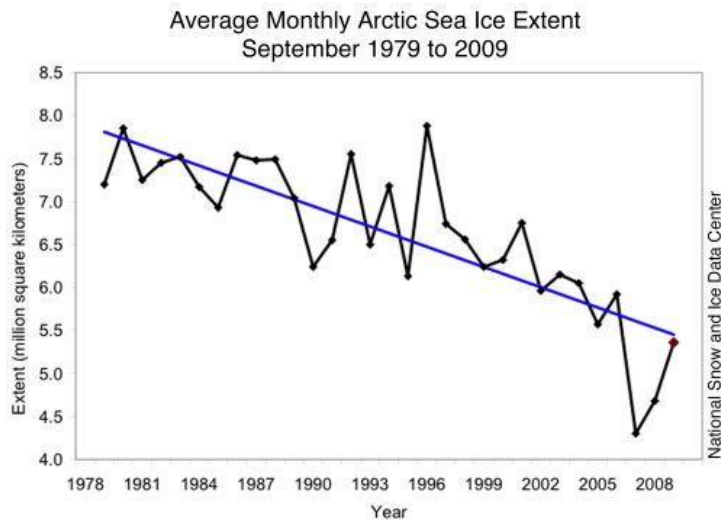
Melting of sea ice that floats does not contribute to sea level rise.

Snow and Ice

Snow reflects sunlight back to space and keeps water vapor from escaping into the atmosphere. Both of these mean more snow → less sunlight and weaker greenhouse effect.

What is a drunken tree?

Arctic sea ice lowest in summer and 2007 summer lowest ever recorded, 2008 and 2009 were both low but not as low as 2007. 2010?? Scientist expect this trend to continue with significant impact to arctic ecosystems.



2007 still holds the record for lowest Arctic sea ice amounts in August or September.

[Youtube Video](#) (3 minutes worth viewing) (Although I would not consider Mr. Miller a climate expert his ideas are worth thinking about)

Although the melting of sea ice does not raise sea level, it does decrease surface salinity which may alter the ocean conveyor belt circulation driven by the sinking of cold salty water in the North Atlantic.



Melting of arctic sea ice will result in accelerated warming in the arctic because as ice melts more sunlight is absorbed locally resulting in warmer temperature yet. Also as ice melt more evaporation takes place increasing the local greenhouse effect of the atmosphere. One concern is that this may increase Arctic land temperatures, causing methane to be released from thawing permafrost.

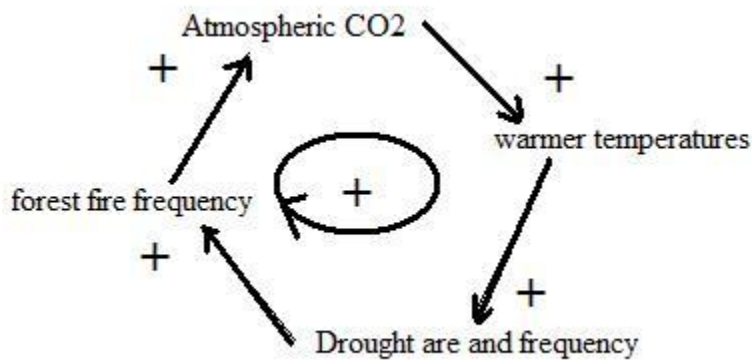
See [youtube video](#) on this (Although I would not consider Mr. Miller a climate expert his ideas are worth thinking about)

Rain and Drought

More water vapor implies more rain.

The total area of regions that experience drought has increased since the 1970s .

Drought also linked to wild fires. Destroying or forests releases CO₂ into the atmosphere in this positive feedback loop (amplifying).



Positive feedback linking drought and forest fires to atmospheric carbon dioxide.

Ecosystems

Longer growing seasons. Tokyo cherry trees are blooming 5 days earlier than they were 50 years ago.

Mosquitoes, birds, and insects are moving North in the northern hemisphere.

Pines beetles

The Human Element

CO2

Preindustrial levels of CO2 were about 280 ppm.

As of 2007 what country emits the greatest amount of CO2 into the atmosphere?

As of 2007 what country has the greatest per capita emission of CO2 into the atmosphere?

Other Greenhouse gases

The atmospheric lifetime of CH4 has increased approximately 3 fold since preindustrial times from 750 to 1800 ppb.

CH4 and Nitrous Oxide fluorinated gases all have lower atmospheric concentrations than CO2 but on a molecule per molecule basis have a stronger greenhouse trapping ability

Are Humans the cause?

Early 20th century warming , mostly from sun.

Over the past 50 years the sun and volcanic eruptions would have likely cooled our planet.

Greenhouse gas increases is presently the only viable explanation for the warming of the last 50 years.

How do we know?

The experts

IPCC

what is IPCC? What is its functions?

Changes in snow, ice , and frozen ground have, with high confidence, increased the size and number of glacial lakes High confidence 8 out of 10.

Other experts

NOAA, NASA, EPA, NCAR, National academy of science, <http://www.climate-science.gov>

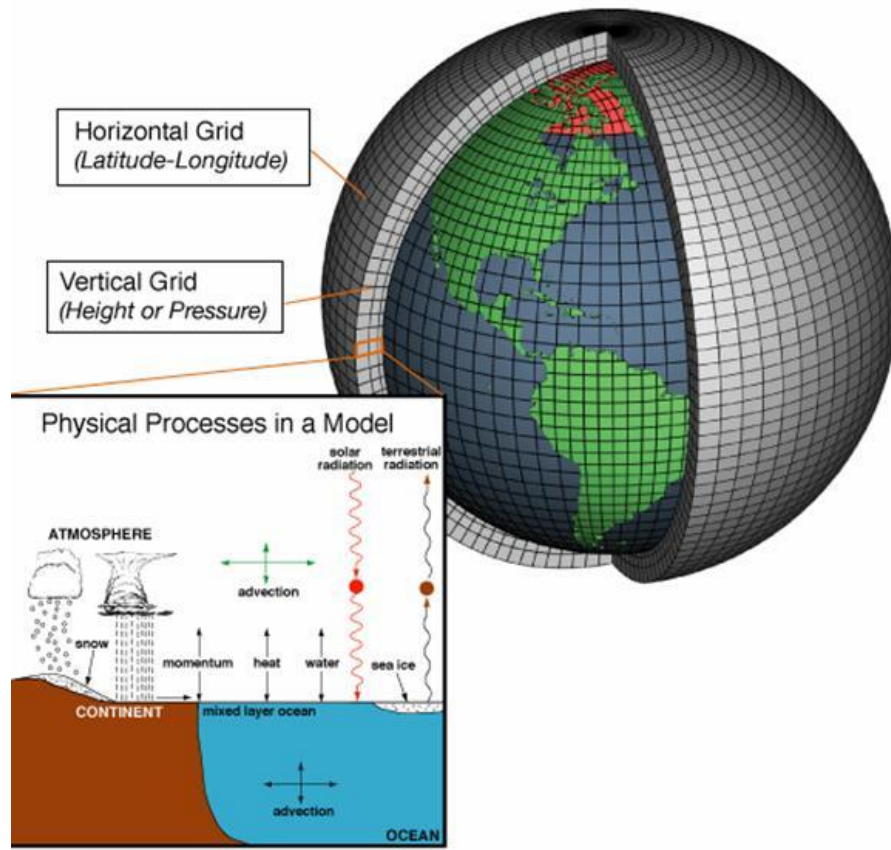
Tools: Data

Paleoclimates Tree rings, ice core, corral growth patterns, climate models

Observations.

Upper atmosphere measurements come from satellite or weather balloon measurements

Tools: Models



What are they? Modern climate models divide earth into roughly $90 \times 2^\circ$ - latitude and $180 \times 2^\circ$ - long and roughly 50 vertical levels (Earth is essentially divided into $90 \times 180 \times 50 = 810,000$ interconnected boxes.) They include ocean processes, soil physical processes, and some include biological limited processes.

Model Chemical and physical processes that drive climate.

Models help us check our understanding of how climate processes work.

Models are the only way to understand climates of the future

Uncertainties Model shortcomings:

1. Limited observations
2. Incomplete understanding of climate processes and their interrelationships
3. Imperfect model representation of these processes
4. relatively large grid boxes that don't represent smaller terrain features.

Climate and Weather models

Unlike numerical weather prediction models Climate models tend to make consistent forecasts of long term climate change and it causes. Climate scientists believe that although the weather system is chaotic and unpredictable beyond 7 to 10 days, the climate system has an element of predictability.

Why should we care?

Only a few degrees?

Why it matters

2 to 13 °F by end of this century.

During the last interglacial 125,000 years ago global temperature are estimated to be about 1°F warmer than today but sea levels were 20 ft higher.

Hotter summers/warmer winters

Summer will be hotter with an increase in the number of heat strokes likely not only because temperatures will increased but also because humidity is likely to increase.

What today is a once in 20 year heat wave event will likely become a once in every 3 or 4 year event by 2050.

The 2003 European heat wave, responsible for up to 35,000 deaths, was a result or global warming and natural variability.

Droughts and Floods

The possibility of increased drought is also linked to an increase in wild fires.

Sea-Level Rise

IPCC estimate a 0.7 to 1.9 feet sea level increase by 2100. A sea level rise of 2 ft. would correspond to a 10,000 square mile loss of coastal land.

The complete loss of either the west Antarctic ice sheet or the Greenland ice sheet could eventually raise sea levels by as much as 20 ft.

Loss of wet lands, damage to fresh water aquifers, and increased coast flooding (particularly in poorer nations) are all likely.

Extreme Weather

Observational Evidence suggest that future warming will make hurricanes become more frequent, less frequent, more intense, less intense?

Tornadoes will likely become more frequent, less frequent, more intense, less intense, or not enough observational data or modeling capabilities to know at present?

Heavy precipitation events will likely become more frequent.

Extreme heat wave events will likely become more frequent.

Other effects

Ocean ecosystems.

pH drop implies an increased acidity making it harder for sea creatures to form calcium carbonate shells.

IPCC predicts that by 2100 the pH of the oceans will be its lowest in 20 million years

Health

Death rates spike an average of 6% during heat waves.

Dengue hemorrhagic fever hit the US for the first time in 2005 in the lower Rio Grande valley.

Milder winter temperatures

Economics

Higher energy, water, and insurance bills.

snow pack will melt sooner causing river flow to decrease in late summer and late summer availability of water scarce in many areas (like the Pacific Northwest) that depend on snow pack for regulated water supply.

Warmer climate may lead to an increased likely-hood of frost damage because crops grow earlier in the season when there is still a chance of a killing frost to occur.

National Security

increases competition for scarce resources, worsens conditions that cause governments to fail, and produces breeding grounds for extremism and terrorism.

Regional effects

all areas of the US are expected to have higher summer temperatures and reduced winter cold stress.

How Sure are scientists?

IPCC Confidence/Probabilities

Signs, Effects, Causes (make sure to click on buttons at the top of the last page of the video)

State the IPCC confidence regarding:

Warming of the climate system over the past century.

Recent warming strongly affects terrestrial biological systems, including earlier spring events and poleward and upward (elevation) shifts in plant and animal ranges.

Humans have influenced the climate since 1750.

Confidence in Future Projections

What is the best estimate for global average temperature change expected by the end of this century for the medium emission scenario? 5.0 °F (2.8 °C)

Confidence in Future Impacts

IPCC scientists are sure with at the 90% confidence level that: 1) by 2080, millions will experience floods due to sea level rise 2) Frequency of warm spells and heat waves will increase, frequency of heavy precipitation events will increase.

Two Positions

It's Not Happening. Observations of the sun show no increase in solar brightness.

Legitimate complaints:

Do we know enough about the drivers of climate to be really sure that we know what causes change?

Are scientists grossly underestimating the complexity of the Earth System?

Are climate models good enough to accurately simulate the complex climate system?

Are there processes that will limit warming naturally by producing a negative feedback?

It's Worse than We Thought?

Arctic Sea Ice is disappearing faster than that originally projected by scientists.

Present day emissions are higher than most IPCC projections 10 years ago.

Are IPCC near-future energy assumptions too optimistic.

Consensus?

97% of all climate scientist believe that Earth has warmed over the past century and 84% of believe that human activity contributes to this global warming.

Be a good consumer of science

Look at the source information

ask questions

Trace the origins of the statement

Check Author credentials

What next?

Strategies

Understand what Adaption and Mitigation mean.

Adaptation strategies:

Build more dikes and dams.

Make air conditioning more available for all especially during heat waves (air conditioning centers).

Use genetically engineered crops that are more stress resistant.

Move coastal cities inland (LA to Riverside concept).

Below are some ways we could possibly reduce CO2 emissions (Mitigation strategies)

Which 8 strategies would you choose to reduce emissions by 8 billion tons?
Click the ones you think should have the highest priority, then click Done.

Increased Efficiency & Conservation

- Efficient vehicles
- Reduced vehicle use
- Efficient buildings
- Efficient electricity production

Carbon Capture & Storage (CCS)

- CCS electricity
- Capture CO₂ at hydrogen plants
- Capture CO₂ at coal-to-synfuels plant

Fuel Switching

- Nuclear electricity
- Natural gas electricity
- Wind electricity
- Solar electricity
- Wind hydrogen

Renewable Energy & Biostorage

- Biofuels
- Forest storage
- Soil storage

Courtesy of Princeton University

Done

Adaptation and Mitigation 2:51 / 2:51

What's next?

What You Can Do ?

Be able to list 6 ideas that make sense to you.

Future Work

Assessments and Research

Extra Pieces Good information and possible resources for extra credit summaries.