Think Globally, Act Locally: Introduction to Climate Change

OBJECTIVES

Students will do the following:

1. Understand difference between climate and weather
2. Identify factors that influence climate
3. Learn about indicators and effects of climate change
4. Employ commonly used metrics to evaluate impact of daily lifestyles choices on global climate

Subjects: Environmental Science, Physics

Time: 90 Minutes

Materials: Access To Computers And Internet Recommended

BACKGROUND MATERIAL

According to data reported by the Goddard Institute for Space Studies, the Earth's average surface temperature has risen by 0.6 to 0.9 degrees Celsius (1.1 to 1.6° F) between 1906 and 2005. The rate of temperature increase has nearly doubled in the last 50 years and is expected to continue rising. This increase in temperature is called global warming. Global warming is mainly caused by rising levels of greenhouse gases in the atmosphere. These gases act like a blanket, trapping energy in the atmosphere and heating the Earth. The heating effect is called the greenhouse effect, and is responsible for maintaining global average temperatures within a livable temperature range. The continued buildup of greenhouse gases in the atmosphere as a result of human activities can change the Earth's climate and have dangerous consequences for humans and the environment. This lesson focuses on sources of greenhouse gases, the impacts of global warming, and the impacts of daily lifestyle choices on climate using a carbon footprint calculator.

The difference between climate and weather

Weather and climate both relate to the atmosphere, but are differentiated based on a measure of time. Weather refers to the condition of the atmosphere over a short period of time, while climate is a description of how the atmosphere "behaves" over relatively long periods of time. Climate change relates to changes in long-term averages of daily weather parameters. In addition to long-term climate change, there are shorter climate variations due to natural phenomena such as El Nino, La Nina and volcanic eruptions.

Weather

Typical weather parameters include hourly or daily temperature, humidity, precipitation, cloudiness, visibility, wind speed, wind direction and atmospheric pressure. Events such as sunshine, rain, clouds, winds, hail, snow, sleet, freezing rain, blizzards, ice storms, thunder storms and even flooding are associated with weather. Data for these phenomena are collected, reported and forecast in the United States by the National Weather Service (NWS). NWS uses radar on the ground, balloons, images from satellites and reports from a large national network of weather reporting stations, to measure air temperature, pressure, wind, and humidity. NWS broadcasts weather reports on radio, and on an Interactive Weather Information Network website at: http://iwin.nws.noaa.gov/iwin/graphicsversion/bigmain.html.

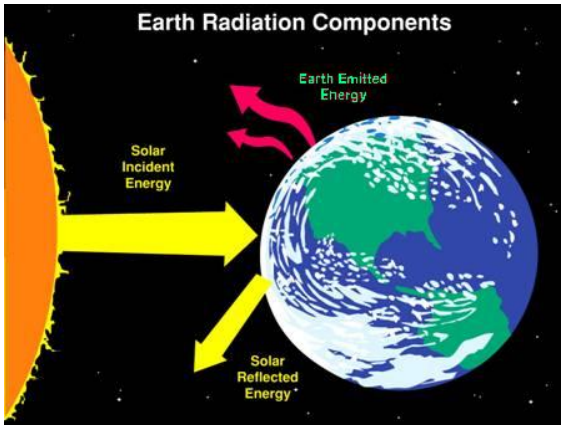
Climate

Climate is the description of long-term pattern of weather in a particular area. Climate is often defined as the average weather for a particular region and time period, typically over time spans of 30-years or more. When scientists talk about climate, they look at averages of measures of weather data that occur over a long period in a particular place. For example, after looking at rain gauge data, lake and reservoir levels, and satellite data, scientists can tell if during a summer, an area was drier than the historical average. If it continues to be drier than normal over the course of many summers, then it likely indicates a change in climate.

According to the Goddard Institute for Space Studies or National Academy of Science?, Earth's average surface temperature has risen by 0.6 to 0.9 degrees Celsius (1.1 to 1.6° F) between 1906 and 2005. Recent records indicate a 0.99 degree Celsius (approximately 1 degree Fahrenheit) rise in average temperatures relative to an average over years 1951-1980. The change in recent winter snows, for example, indicate that the climate has changed over the past 30-40 years. If summers seem hotter lately, then recent climate may have changed. In several regions, springtime has been reported earlier now than 30 years ago. An earlier springtime is indicative of a possible change in the climate.

Processes that impact Earth's radiation budget

The sun's energy fuels the Earth's temperature. In the absence of human influences, the radiation budget explains how much energy is received by the Earth from the sun and how much is radiated back to outer space. The radiation budget keeps the earth's temperature within a livable range. Three components that constitute the radiation budget are:



- Incident (or incoming) solar energy – energy received from the sun in the form of shortwave UV radiation.
- Reflected (or outgoing) solar energy – energy reflected from the earth by clouds and atmosphere.
- Emitted (outgoing) energy: Earth absorbs part of the shortwave radiation and emits back longwave radiation.

Albedo

Albedo is the fraction of solar energy (shortwave radiation) reflected from the Earth back into space. It has no dimensions and varies between 0-1; and refers to the "whiteness" of the surface. A value of zero means the surface is a "perfect absorber" that absorbs all incoming energy. Absorbed solar energy can be used to heat the surface or, when ice is present, melt the surface. A value of 1 means the surface is a "perfect reflector" that reflects all incoming energy. Fresh snow, has an albedo of 0.95, so most sunlight hitting a snowy surface bounces back towards space. (This is similar to white shiny surfaces that have the most glare). Fresh asphalt has an albedo of 0.04, meaning it absorb most of the incident

energy (roads are almost impossible to walk on bare foot in hot weather), while oceans have an albedo around 0.06. Earth's average albedo is estimated around 0.30, which means the Earth's surface on an average reflects 30% of the incoming sunlight. Interestingly, if the Earth's entire surface is covered in ice, its estimated albedo would be about 0.84. It means that Earth would then reflect 84% of the sunlight. Similarly, if the earth is covered by a dark green forest all over, the albedo would be around 0.14 which means 86% sunlight would get absorbed leaving 14% only to get reflected

Greenhouse gases and global warming

Composition of Earth's atmosphere

Earth's atmosphere is composed of nitrogen (78%), oxygen (21%) and argon (0.9%). Other trace gases include carbon dioxide, nitrous oxides, methane, and ozone that total a tenth of one percent (0.1%) of the atmosphere. Water vapor concentrations can vary from 0-4% of the atmosphere depending on location and time of the day. In cold, dry artic regions, water vapor accounts for less than 1% of the atmosphere, while in humid, tropical regions; it can account for almost 4% of the atmosphere. The composition of the atmosphere, is one of the key factors in determining its ability to transmit sunlight and trap infrared light, thereby influencing the radiative budget and the Earth's climate.

Greenhouse gases (GHG's) and greenhouse effect

A greenhouse gas (GHG) in the atmosphere absorbs and emits radiation within the thermal infrared range. Primary GHGs in Earth's atmosphere include water vapor, carbon dioxide, methane, nitrous oxide, and ozone. About half the light reaching Earth's atmosphere passes through the air and clouds to the surface, where it is absorbed and then radiated upward in the form of infrared heat. About 90 percent of this heat is then absorbed by the GHG's and radiated back toward Earth's surface. This effect is called the greenhouse effect. GHG's act like a blanket around the Earth, trapping heat and warning the air temperature at the Earth's surface to a life-supporting average of 59 °F (15 °C). Without greenhouse gases, the average temperature of Earth's surface would be about 0 °F (-18 °C). By percentage of contribution, greenhouse effect can be attributed to water vapor (36-70%), CO2 (9-26%), methane (4-9%) and ozone (3-7%). Different GHG's impact the greenhouse effect differently, based on (a) nature of the species, (b) abundance in the atmosphere, and (c) lifetime in the atmosphere. The "warming" impact of different species are quantified using the global warming potential metric.

Global warming

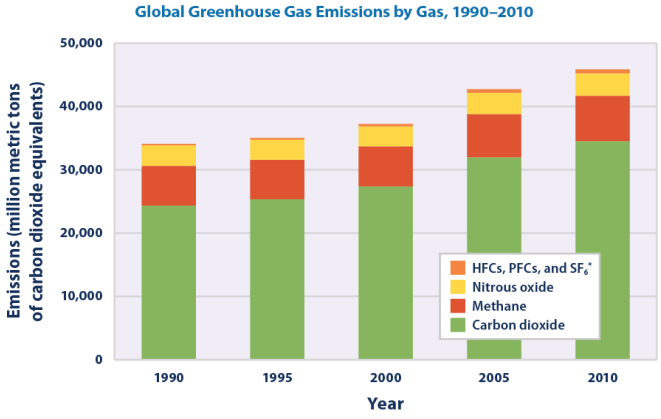
Global warming and climate change are terms for the observed century-scale rise in the average temperature of the Earth's climate system and its related effects. Since the Industrial Revolution (~ year 1850) the emissions of greenhouse gases in the atmosphere has increased, leading to increased radiative forcing from increased levels of CO_2, methane, tropospheric ozone, chlorofluorocarbons (CFCs), hydrofluorocarbons (HFCs) and nitrous oxide. Concentrations of CO_2 and methane had increased by 36% and 148% respectively since 1750. These levels are much higher than at any time during the last 800,000 years, the period for which reliable data has been extracted from ice cores. In 2013, the Intergovernmental Panel on Climate Change (IPCC), concluded that "It is *extremely likely* that human influence has been the dominant cause of the observed warming since the mid-20th century."

Global warming potential (GWP)

Global warming potential (GWP) is a relative measure of how much heat a GHG traps in the atmosphere as compared to a similar mass of CO_2. A GWP is calculated over a specific time interval, commonly 20, 100, or 500 years. GWP is expressed as a factor of carbon dioxide. CO_2 has a GWP of 1. GWP of other important GHG's include methane (86 over 20 years), nitrous oxide (298 over 100 years). A list of GWPs for different species, associated life times and different time horizons is available at: http://unfccc.int/ghg_data/items/3825.php.

Sources of GHG's

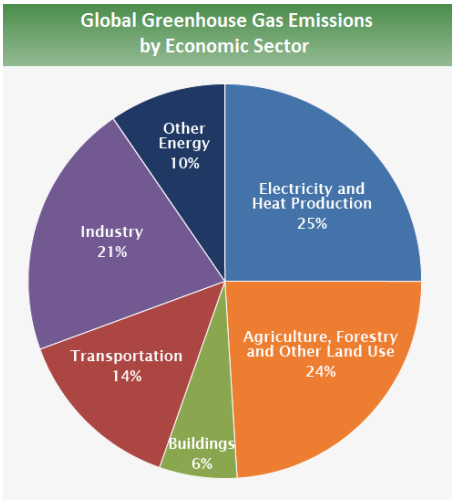
In 2010, estimated worldwide emissions from human activities totaled nearly 46 billion metric tons of greenhouse gases, expressed as carbon dioxide equivalents. This represents a 35 percent increase from

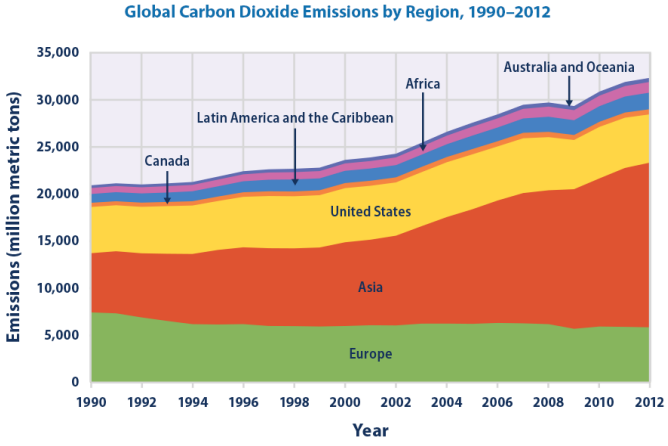


* HFCs are hydrofluorocarbons, PFCs are perfluorocarbons, and SF_6 is sulfur hexafluoride.

Data sources:
- WRI (World Resources Institute). 2014. Climate Analysis Indicators Tool (CAIT) 2.0: WRI's climate data explorer. Accessed May 2014. http://cait.wri.org.
- FAO (Food and Agriculture Organization). 2014. FAOSTAT: Emissions—land use. Accessed May 2014. http://faostat3.fao.org/faostat-gateway/go/to/download/G2/*/E./bird/bacc/techreport.html.

For more information, visit U.S. EPA's "Climate Change Indicators in the United States" at www.epa.gov/climate-indicators.





Data source: WRI (World Resources Institute). 2015. Climate Analysis Indicators Tool (CAIT) 2.0: WRI's climate data explorer. Accessed December 2015. http://cait.wri.org.

For more information, visit U.S. EPA's "Climate Change Indicators in the United States" at www.epa.gov/climate-indicators.

1990. The distributions by species and sector are indicated below (Source: IPCC, 2014).

- CO_2 is emitted primarily from burning of fossil fuels such as oil, natural gas and coal, solid waste, trees and wood products. Changes in land use also play a role. Deforestation and soil

degradation release carbon dioxide to the atmosphere, while forest regrowth can remove CO2 from the atmosphere. Human activities have increased atmospheric CO_2 concentration by more than a third since the Industrial Revolution began. This is the most important long-lived "forcing" of climate change.

- Methane is emitted from both natural sources and human activities, including the decomposition of wastes in landfills, agriculture, and especially rice cultivation, as well as ruminant digestion and manure management associated with domestic livestock. On a molecule-for-molecule basis, methane is a far more active greenhouse gas than carbon dioxide, but also one which is much less abundant in the atmosphere.
- Nitrous oxide is emitted from denitrification processes from soils, agricultural processes and industrial activities, as well as during combustion of fossil fuels and solid waste. Also known as "laughing gas," nitrous oxide is ranked third behind carbon dioxide and methane in terms of contribution to global warming. The gas is 310 times more effective in trapping heat than carbon dioxide. Sixty percent of the nitrous oxide in the atmosphere is produced naturally.
- Chlorofluorocarbons (CFCs) are synthetic compounds of industrial origin used in a number of applications for commercial, industrial and household uses. CFCs are also GHGs. However, CFCs are regulated in production and release to the atmosphere by international agreement due to their ability to contribute to destruction of the ozone layer.

Impacts of GHG's

Consequences of changing the natural atmospheric greenhouse are difficult to predict, but several studies have linked increasing GHG emissions to rising average temperatures. Possible impacts of global warming could include the following:

- Increasing average global temperatures could result in accelerated warming in some regions of the world. Winters could be shorter, resulting in early onset of spring.
- Warmer conditions will probably lead to more evaporation and precipitation overall, but individual regions will vary, some becoming wetter and others dryer. This could result in an increased risk of flooding and impact crop planting schedules.
- Sea level increases are strongly tied to increased global temperatures. A stronger greenhouse effect can partially melt glaciers and other ice, increasing sea level. Warming of oceans, will also result in expansion, contributing further to sea level rise.
- Meanwhile, some crops and other plants may respond favorably to increased atmospheric CO_2, growing more vigorously and using water more efficiently. At the same time, higher temperatures and shifting climate patterns may change the areas where crops grow best and affect the makeup of natural plant communities. Climate change will impact agriculture and food production around the world due to the effects of elevated CO_2 in the atmosphere, higher temperatures, altered precipitation patterns, increased frequency of extreme events, and increased risk of weeds, pests and pathogens.
- Increased temperatures are also linked to increased risks for vector borne diseases, such as malaria, likely resulting in increased disease burden. Early onset of spring, could also aggravate allergic reactions and increased incidence of asthma. Climate change was estimated to have been responsible for 3% of diarrhea, 3% of malaria, and 3.8% of dengue fever deaths worldwide

in 2004. Total attributable mortality was about 0.2% of deaths in 2004; of these, 85% were child deaths. **we need to add a reference here**

- Drinking water resources could be stressed under increased temperatures. Sea level rise could increase salinization of estuaries and groundwater sources. Melting of glaciers could temporarily increase flows in large river systems; however under persistent temperature rises, it could impact flows of surface water.

Using Carbon Footprint Metric to Link Human Activity to Global Climate

A carbon footprint is defined as the total amount of GHGs emitted either directly or indirectly to support human activities, usually expressed in equivalent tons of carbon dioxide (CO_2). Most of the carbon footprint emissions for the average U.S. household come from "indirect" sources, e.g. fuel burned to produce goods far away from the final consumer. These are distinguished from emissions which come from burning fuel directly in one's car or stove, commonly referred to as "direct" sources of the consumer's carbon footprint. The carbon footprint is a very powerful tool to understand the impact of personal behavior on global warming. It can provide a "reality" check for individuals who would like to identify impacts of their local actions on global climate.

Ways to reduce individual carbon footprint

The most common way to reduce the carbon footprint of humans is to reduce, reuse, recycle and refuse. By adopting this multi-pronged approach, individuals can adjust their daily lifestyle choices to reduce their carbon footprint. Examples include use of reusable items such as metal containers for beverages. Identifying products that can be recycled or composted, can result is as much reduction of 1.2 tons CO_2/annum for a 4 member household. Reducing reliance on fossil fuels by driving less, choosing to commute by walking or biking or taking mass transportation can reduce carbon footprint. Similarly, reducing usage of air conditioning and heating, using energy efficient appliance, improving home insulation and using climate appropriate building materials can reduce carbon footprints. Choice of diet is a major influence on a person's carbon footprint. Animal sources of protein (especially red meat), rice (produced in high methane-emitting paddies), foods transported long distance and/or via fuel-inefficient transport (e.g., highly perishable produce flown a long distance), and heavily processed and packaged foods are among the major contributors to a high carbon diet. Scientists at the University of Chicago ADD A REFERENCE have estimated "that the average American diet – which derives 28% of its calories from animal foods – is responsible for approximately one and a half more tonnes of greenhouse gasses (as CO_2 equivalents) per person, per year in comparison to a plant based diet. An individual can use carbon footprint calculators to identify the choices in their life that most impact their footprint, and work towards minimizing their individual impacts.

PROCEDURE

I. Preliminary Lecture

Setting the Stage

Establish basic concepts in climate change, sources and impacts using PowerPoint presentations and online videos. (See sample powerpoint presentation in Appendix A.) The background information section can be used to develop the lecture and by referencing

additional on-line information found in the Resources section. Lecture session is estimated between 25-35 minutes. A starter set of PowerPoint Slides is provided in Appendix A.

II. Activity A: Using A Climate Model

Setting the Stage

Students will use a simple online climate model (developed by UCAR Office of Education and Outreach) to simulate the impact of increasing GHG emissions on Earth's surface temperature under different emissions scenarios. The goal of this activity is to establish impact of atmospheric CO_2 on Earth's atmosphere, and understand how increases in GHG's impact global average temperatures

Resource to Access

- http://eo.ucar.edu/staff/rrussell/climate/modeling/co2_climate_model.html. This model can also be accessed offline, if a copy is downloaded.
- A sample worksheet (Handout A) is provided to guide students through this activity.

Follow up

Outcomes from this activity should be discussed in class before moving to Activity B. Teachers should review the GHGs in the atmosphere, identify difference between emissions and concentrations of GHG's and how it relates to the radiation budget.

Extension

Activity A can be extended to predict how future temperatures could increase under multiple emissions scenarios. Country wide GHG emissions estimates are reported in the CAIT Climate Data Explorer (maintained by the World Resources Institute; http://cait.wri.org/historical). Historical emissions can be used to construct different emissions scenarios using the CAIT Climate Data Explorer. Emissions totals can then be used to provide inputs to the climate model.

III. Activity B: Estimating Carbon Footprint

Setting the Stage

Students will calculate their carbon footprint to understand their impact on climate change using an online calculator. A worksheet is provided to guide students through using the calculator and interpreting results.

Resources

- Online calculator: http://www.nature.org/greenliving/carboncalculator/
- A sample worksheet (Handout B) to interpret results from the carbon calculator.

Follow-up

Students should be encouraged to share their results, and their observations with the classroom. A discussion should be initiated for students to explore solutions they can implement in their everyday life to minimize the impacts of their local actions on global climate.

Extension

If time permits, students can scale their carbon footprints to global scale by multiplying global population. The emissions estimates can then be fed into the simple online climate model (in Activity A), to link individual emissions to future CO_2 concentrations and average global temperatures.

IV. Follow-up

At least 20 minutes should be provided at the end for in-class discussion to tie back Activities A and B with background information. If time permits, students may be directed to brainstorm about identifying sources that can be controlled, potential solutions to emissions control, costs involved and effort to deploy solutions regionally.

RESOURCES

Difference between Weather and Climate

https://www.nasa.gov/mission_pages/noaa-n/climate/climate_weather.html

Global Warming Potential

Sources of GHGs

Source: IPCC, 2014

http://unfccc.int/ghg_data/items/3825.php

Weather

http://iwin.nws.noaa.gov/iwin/graphicsversion/bigmain.html

Online Climate Model

http://eo.ucar.edu/staff/rrussell/climate/modeling/co2_climate_model.html

Carbon Footprint Calculator

http://www.nature.org/greenliving/carboncalculator/

Recommended resources for background information

- https://earthobservatory.nasa.gov/Features/GlobalWarming/page2.php
- https://www.nasa.gov/mission_pages/noaa-n/climate/climate_weather.html
- http://www.globalchange.gov/
- http://ipcc.ch/pdf/assessment-report/ar5/syr/AR5_SYR_FINAL_SPM.pdf
- https://www.epa.gov/ghgemissions/overview-greenhouse-gases

Recommended videos:

- https://science-edu.larc.nasa.gov/multimedia/erbe/c5.ERBE.mov

Handout for Activity A: Use of a Simple Climate Model

Go to: http://eo.ucar.edu/staff/rrussell/climate/modeling/co2_climate_model.html

1. Identify what parameters are included on the x-axis and y-axis
2. Setting up the model:
    a. Set CO2 emissions at 10 Gigatons-C/year (representative of year 2010)
    b. Change the time step to 20 years (outputs can be seen at 20 year intervals)
    c. Change the temperature unit to Fahrenheit
    d. Select Step Forward
3. Fill in the following table based on your observations:

End year	2010	2030	2050	2070	2090	2110
CO2 emissions (GtC per year)	10					
CO2 concentrations (ppmc)						
Global average temperature (deg F)						

4. How much does the temperature increase from 2010 to 2110?
5. Rerun with different Emission scenarios?

Handout for Activity B: Estimating Carbon Footprints using a Carbon Calculator

Go to the carbon calculator: http://www.nature.org/greenliving/carboncalculator/

1. Go through all the tabs to input your daily activity into the calculator. Use your home zip code, and average salary of $52,000 for the United States.
2. Fill in the following:
    a. My carbon footprint: _____ tons CO_2 equivalent/year
    b. Carbon footprint of similar households: _____ tons CO2equivalent/ year
    c. Are you better or worse than average?
3. Click on the pie chart symbol below the results.
    a. What were the two biggest contributors to your carbon footprint?
    b. What can you do to reduce carbon emissions?
4. If time permits, students can repeat the carbon calculator exercise by:
    a. Identifying individual actions, to reduce emissions by 20%
    b. Identifying specific practices, like modifying water usage or diets.
    c. Estimate how these local changes in lifestyle, impact carbon footprints.

APPENDIX A: Sample PowerPoint Slides for Introducing Background Information