Lesson Plan: Teach the Earth's Climate System Through Simulations (Build Your Own Earth)

Lesson Plan developed with contribution from Pratibha Songara.

As an **Undergraduate Earth Sciences**, **Environmental Sciences, or Geography** teacher, you can use this lesson plan to teach the Earth's climate system and help your students understand different aspects of Earth's climate through the use of simulations. This lesson plan is based on the web-based tool 'Build Your Own Earth' developed by the University of Manchester.

This lesson plan provides an introduction to Earth's climate system, an overview of the **Build Your Own Earth simulator** with multiple Earth configurations that will help your students understand several aspects of what determines the climate of planet Earth, a guide to the use of the simulator in a classroom, and an assignment with select configurations that can reinforce learning about the climate system and climate change through this innovative digital pedagogical practice.

There are several factors that impact the surface temperature and the climate of the planet. These include the role of the sun and **solar flux** incident on the planet, changes in the solar energy flux received on planet Earth, **Earth's orbital parameters and Milankovitch cycles**, the roles of the atmosphere and the greenhouse effect, the hydrosphere, the lithosphere, the biosphere, the cryosphere, the anthroposphere, and their interactions on a variety of spatial and temporal scales. This lesson plan demonstrates the use of the Build Your Own Earth simulation to explain select aspects of the **Earth's climate system** and can be used to teach students the role that different factors play in determining Planet Earth's climate.

Thus, the use of this lesson plan allows you to teach Climate Science and Climate Change in your **Earth Sciences, Environmental Sciences,** and **Geography** classrooms. This lesson plan is particularly effective to use in a flipped classroom and as a blended learning educational resource.

Use this lesson plan to help your students find answers to:

1. What would Earth's climate be like if the sun were faint? What would it be like if the sun was warmer?

2. What determines the average surface temperature of planet Earth?

3. What would Earth's average surface temperature be if we had no greenhouse gases in the atmosphere? If the CO_2 levels were double of pre-industrial levels? In the year 2100?

4. What was the average surface temperature of the Earth during the Last Glacial Maximum? In the Jurassic (170 million years ago)? In the Cambrian (540 million years ago)?

5. What would Earth's climate be like if it was entirely covered in Ice? If it was an Aquaplanet? If it was a Terraplanet?

About the Lesson Plan

Grade Level: Undergraduate

Discipline: Earth Sciences, Environmental Sciences, Geography

Topic(s) in Discipline: Earth's Climate System, Climate Change

Climate Topic: Planetary Climate

Location: Global

Access: Online

Language(s): English

Approximate Time Required: 45 min- 2 hr 15 min approximately

1 Contents

1. Video Lectures (1 hr 30 min)

Two video lectures by Prof Raghu Murtugudde that explain the Earth's climate system. It also explains what are the factors that determine the climate of planet Earth, what causes natural variability in the Earth's climate on different time scales and how do you distinguish between natural variability and anthropogenically forced global warming.

This can be accessed at:
https://www.youtube.com/watch?v=tGQKk6QtUh4&list=PLZbgNdSTyWDbHe1onWK9SULbPxCuAMi1Z&index=3&t=0s
and
https://www.youtube.com/watch?v=W6MoOl-mdqY&list=PLZbgNdSTyWDbHe1onWK9SULbPxCuAMi1Z&index=3

2. Introduction to Simulator 'Build Your Own Earth' (15 min)

The Build Your Own Earth simulator developed by the University of Manchester to understand Earth's climate system.

The Build Your Own Earth simulator can be accessed at:
http://www.buildyourownearth.com/index.html

Tutorials can be accessed at:
http://www.buildyourownearth.com/tutorials.html

3. Classroom/Laboratory Activity (30 min)

A classroom/ laboratory activity that uses the Build Your Own Earth simulator to guide learning about Earth's climate system and the role that different factors play in determining Earth's climate and changes to it.

4. Suggested questions/assignments for learning evaluation

- What would Earth's climate be like if the sun were faint? What would it be like if the sun was warmer?
- What determines the average surface temperature of planet Earth?
- What would Earth's average surface temperature be if we had no greenhouse gases in the atmosphere? If the CO2 levels were double of pre-industrial levels? In the year 2100?
- What was the average surface temperature of the Earth during the Last Glacial Maximum? In the Jurassic (170 million years ago)? In the Cambrian (540 million years ago)?
- What would Earth's climate be like if it was entirely covered in Ice? If it was an Aquaplanet? If it was a Terraplanet?

2 Step-by-step User Guide

Here is a step-by-step guide to using this lesson plan in the classroom/laboratory. We have suggested these steps as a possible plan of action. You may customize the lesson plan according to your preferences and requirements.

1. Introduction to the Earth's Climate System

Introduce the Earth's climate system to your students through the video lectures 'Introduction to Climate Science – Lectures 1 and 2' by Prof Raghu Murtugudde, University of Maryland, and developed by the National Resource Center on Climate Change at the Indian Institute of Science Education and Research (IISER), Pune. These lectures were developed to train undergraduate educators to effectively teach Climate Change in their classrooms.

Emphasize the following topics from the video lecture: What determines the climate of planet Earth, the significant role of the sun and the solar energy flux received on the planet, changes in the solar energy flux due variations in Earth's orbital parameters, Milankovitch cycles, the role of the atmosphere and the greenhouse effect of the atmosphere, the hydrosphere, the lithosphere, the cryosphere, the biosphere, the anthroposphere and interactions between them on a variety of time scales.

This resource can be accessed at:
https://www.youtube.com/watch?v=tGQKk6QtUh4&list=PLZbgNdSTyWDbHe1onWK9SULbPxCuAMi1Z&index=3&t=0s

and
https://www.youtube.com/watch?v=W6MoOl-mdqY&list=PLZbgNdSTyWDbHe1onWK9SULbPxCuAMi1Z&index=3

2. Introduction to the Simulator 'Build Your Own Earth'

Introduce your students to the Build Your Own Earth simulator developed by the University of Manchester. Direct your students to watch the short tutorials on how to use the simulator.

The Build Your Own Earth simulator can be accessed at:
http://www.buildyourownearth.com/index.html
Tutorials can be accessed at:
http://www.buildyourownearth.com/tutorials.html

3. Classroom/Laboratory Activity

Begin by providing your students with an overview of the simulator. You may use the following description.

- Build Your Own Earth is a web-based tool that is based on the Fast Ocean-Atmosphere Model – a global circulation model that features coupled models of sea ice, oceanic, and atmospheric processes.
- This tool provides 50 different Earth configurations in three categories: Recent, Ancient, and Alien Earths. Within each type of earth, the user has the option to vary several factors and determine the average surface temperature and Earth's climate.
- The Recent Earth category is based on present day configurations, while the Ancient Earth category includes a series of paleo-climate simulations of past geologic eras from the Last Glacial Maximum around 21,000 years ago to the Ediacaran 600 million years ago.
- The Alien Earth category includes options to visualize the climate of the planet if it were an aquaplanet, terra planet, or ice planet, amongst others.

Provide instructions to your students on how to use this simulator. You may use the following instructions to help students get familiar with the simulator.

1. To begin, use the selector (EARTH) to choose which earth to display - Recent, Alien or Ancient. As you select the Earth-type, you will see the Earth properties panel change to reflect the properties of the selected Earth type.
2. Use the climate property selector - Atmosphere, Ice, Land, or Ocean - to choose the climate property that will be displayed for the selected Earth.

3. Once you have selected the Earth-type and climate property, select the “view climate model” button to enter the climate viewer screen. Now you will be able to see the selected Earth with the chosen climate property displayed in the climate viewer.
4. The climate viewer cycles through the climate data for each month of the year. You can select the Pause button to pause play or drag the timeline slider to any month.
5. You can use the View Switcher to change the view shown in the climate viewer to the North Pole, South Pole, International Dateline (180°), or the Prime Meridian (0°).
6. You can add another Earth to the viewer for comparison. To do this, select the Add Earth 2 tab. You can now see two Earths displayed on the climate viewer separated by a divider. The Earth on the left is Earth 1 and the Earth on the right is Earth 2. You can move the slider left and right to see more of each Earth.
7. You can change the climate property that is being shown for each Earth at any time.
8. You can select the download image button to download an image showing the current view in the climate viewer.

Note that the different configurations for the Earth are

Earth

- Recent - Current Day 2015, No Greenhouse gases, Preindustrial control, and others.
- Ancient - 21 Ka: Last Glacial Maximum, 20 Ma: Miocene, and others.
- Alien - Aquaplanet, Ice planet, Terra planet, and others.

Climate Property

- Atmosphere - Mean temperature, Total Precipitation, and others.
- Ice - Sea Ice Fraction, Sea Ice Thickness, and others.
- Land - Land Surface Albedo, Cloud-Free Surface Albedo, and others
- Ocean - Ocean Currents, Ocean Salinity, and others.

Give your students an assignment and ask them to answer the following questions. The solutions to the assignment are provided as a separate downloadable document.

Q 1. What would Earth’s climate be like if the sun were faint? What would it be like if the sun was warmer?
Q 2. What would Earth’s average surface temperature be if we had no greenhouse gases in the atmosphere?
Q 3. What would Earth’s average surface temperature be if the CO_2 levels were double of pre-industrial levels? In the year 2100?
Q 4. What was the average surface temperature of the Earth during the Last Glacial Maximum? In the Cambrian (540 million years ago)?
Q 5. What would Earth’s climate be like if it was entirely covered in Ice?
Q 6. What would Earth’s climate be like if it was an Aquaplanet? If it was a Terraplanet?

3 Learning Outcomes

The tools in this lesson plan will enable students to:

- learn about what determines the climate of planet Earth
- understand the role of the sun and incident solar energy flux in determining the average surface temperature
- understand the role of the role of the atmosphere and the greenhouse effect of the atmosphere
- determine the roles of the cryosphere, hydrosphere, and lithosphere in the Earth's climate system
- use simulators to understand the Earth's climate system and climate change

5 Credits/Copyrights

All the teaching tools in our collated list are owned by the corresponding creators/authors/organizations as listed on their websites. Please view the individual copyright and ownership details for each tool by following the individual links provided.
We have selected and analyzed the tools that align with the overall objective of our project and have provided the corresponding links. We do not claim ownership of or responsibility/liability for any of the listed tools.

1. Video Lectures; 'Introduction to Climate Science – Lectures 1 and 2'

By Prof Raghu Murtugudde, University of Maryland, and developed by the National Resource Center on Climate Change at the Indian Institute of Science Education and Research (IISER), Pune.

2. Simulation; 'Build Your Own Earth'

Developed by University of Manchester, UK.