Games & Simulations for Climate Education

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Some of our games originally developed for exhibit touchscreens
Exhibit Touchscreens

Similar to development for mobile touch devices (smartphones, tablets)
All models are wrong, but...

“Essentially, all models are wrong, but some models are useful.”

- George E. P. Box (1951)
Modeling Planetary Energy Balance

• Calculate theoretical temperature of a planet with some simple math
• Discover that Earth would be frozen without the greenhouse effect

Science Topics

• Blackbody Radiator and the Stefan-Boltzman Law
• Conservation of Energy (Energy In = Energy Out)
• Albedo
Earth’s Energy Balance

Temperature = \(\sqrt{\frac{\text{Brightness} \times (1 - \text{Albedo})}{4 \times \text{constant}}}\)

\[240 = \sqrt{\frac{1366 \times (1 - 0.45)}{4 \times 5.67 \times 10^{-8}}} = \sqrt{\frac{1366 \times 0.55}{2.77 \times 10^{-7}}} = \sqrt{\frac{751}{2.77 \times 10^{-7}}} = \sqrt{3.31 \times 10^9}\]

URL: scied.ucar.edu/earths-energy-balance
LASP: Kelvin Climb

Paint the planet to see how coloring affects albedo, and note how the albedo affects the planet’s blackbody temperature. Click ‘Next’ when finished.

URL: lasp.colorado.edu/home/education/k-12/project-spectra/kelvin-climb-interactive
Add an Atmosphere with Greenhouse Gases

This planet could have lakes of liquid water. Its atmosphere could contain nitrogen or oxygen, and may contain greenhouse gases such as carbon dioxide or methane.

Sizes and distances not to scale.

Change the atmosphere thickness and greenhouse strength and see what your planet might look like from the surface. What sort of atmosphere is required in order to have liquid water on your planet? Click 'next' when finished.
This is a completely black planet with no atmosphere. Drag the planet to change its distance from the Sun, and adjust its mass and density to see how temperature is affected. Click ‘Next’ when done.
### The Planet With Surface Features and a Non-Absorbing Atmosphere

1. Enter an appropriate albedo in the grey box below, then examine the resulting solar energy absorbed at the planet's surface and its surface temperature in the boxes to the right.
2. To change the luminosity or distance, return to the first page and make your changes there.

#### Solar Energy Reaching the Planet's Surface Each Second (Watts/meter²)
- **Average:** 341.79
- **Maximum:** 1367.17

#### Energy Absorbed At the Planet's Surface Each Second (Watts/meter²)
- **Average:** 235.84
- **Maximum:** 943.35

#### Resulting Surface Temperature

| Black Body Planet | 278.6 | 5.5 | 41.3 |
| Planet With Albedo | 254.0 | .19 | 2.6 |

#### Average Reflectivity of the Planet (or albedo)
- **0.310**

#### Suggested Average Albedos For Modeling Planets In Our Solar System

<table>
<thead>
<tr>
<th>Planet</th>
<th>Albedo</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mercury</td>
<td>0.11</td>
</tr>
<tr>
<td>Venus</td>
<td>0.76</td>
</tr>
<tr>
<td>Earth</td>
<td>0.306</td>
</tr>
<tr>
<td>Mars</td>
<td>0.25</td>
</tr>
<tr>
<td>Jupiter</td>
<td>0.54</td>
</tr>
<tr>
<td>Saturn</td>
<td>0.34</td>
</tr>
<tr>
<td>Uranus</td>
<td>0.3</td>
</tr>
<tr>
<td>Neptune</td>
<td>0.29</td>
</tr>
<tr>
<td>Pluto</td>
<td>0.3</td>
</tr>
</tbody>
</table>

### URL:
[icp.giss.nasa.gov/education/geebitt](http://icp.giss.nasa.gov/education/geebitt)
Greenhouse Effect - PhET

URL: phet.colorado.edu/en/simulation/greenhouse
What is the future of Earth’s Climate? module
URL: concord.org/stem-resources/what-future-earth’s-climate
URL: authoring.concord.org/activities/279/pages/1736/c05ea8e7-f131-447d-8b68-ef31c4d2206b
What is a “model”? activity

URL: littleshop.physics.colostate.edu/activities/atmos1/WhatIsAModel.pdf
Carbon Dioxide Emissions (Gigatons Carbon per Year)

5.8

Time step size:
5 years

Show which graphs?
- CO2 Emission Rate
- Temperature

Temperature scale: Celsius

Highest temperature: 17 degrees

Highest concentration: 800 ppmv

URL: scied.ucar.edu/simple-climate-model
Compare Graphs of IPCC Scenarios

Version for 5th Assessment Report under development

URL: scied.ucar.edu/compare-ipcc-scenarios-interactive
Climate Sensitivity Calculator

CO₂ in atmosphere doubles... 
... temperature goes up 3 degrees

URL: scied.ucar.edu/climate-sensitivity-calculator
Climate Bathtub Animations

URL: scied.ucar.edu/climate-bathtub-model-animations
Climate Interactive – Climate Bathtub Simulation

Climate Interactive – MIT Greenhouse Gas simulator

Also:

- World Climate roleplaying activity
- World Energy
- En-ROADS, C-ROADS and C-Learn

URL: www.climateinteractive.org/tools/mits-greenhouse-gas-simulator/
Natural gas is a non-renewable fossil fuel. People burn natural gas to heat buildings, cook food, generate electricity, and power vehicles. Natural gas supplies nearly one-quarter (22.9%) of the world’s energy - about 31.7 petawatt-hours per year.

Natural gas is relatively "clean" compared to other fossil fuels. Burning natural gas emits much less carbon dioxide per kilowatt-hour of energy produced than does burning petroleum or coal. Natural gas is more challenging to store and to transport than are other fossil fuels.

- Natural gas shall be used to produce 25 petawatt-hours of energy.
- It is reasonable to assume that natural gas is 200 kilograms of carbon dioxide for every megawatt-hour of energy produced.
- It is reasonable to assume that natural gas is 3 cents per kilowatt-hour of energy produced.
- The impact on the environment caused by the use of natural gas is Slightly Bad.
- The public, businesses, and/or government support Somewhat Support use of natural gas.

Natural gas costs about $14 per thousand cubic feet sold to residential customers. That works out to about 4.7 cents per kilowatt-hour of energy produced. When used to generate electricity (instead of for heating), natural gas costs about 3.7 cents per kWh of electricity delivered to customers.

The price of natural gas had remained quite steady for many years. As shown in the graph, prices throughout most of the 1980s and 1990s hovered around $6 per thousand cubic feet. However, the cost of natural gas rose sharply in the past decade as prices more than doubled during that time.

URL: scied.ucar.edu/ruler-world
URL: www.bbc.co.uk/sn/hottopics/climatechange/climate_challenge
Hoping to make a suite of paleoclimate sims; ice cores, sea sediments, etc.

URL: scied.ucar.edu/tree-ring-interactive
Glacier Model - PhET

URL: phet.colorado.edu/en/simulation/glaciers
NASA’s Climate Kids – OFFSET!

URL: climatekids.nasa.gov/offset
Atmospheric Chemistry Memory Game

Includes the GHGs carbon dioxide and methane
Advanced level: compare equivalent, not identical, representations

URL: scied.ucar.edu/molecules-memory-game
Cloud Sorting Game

Sort Clouds by Altitude

- Cirrus
- Contrails
- Cirrostratus
- Stratocumulus
- Stratus
- Altostratus
- Altostratus
- Cirrostratus

High Clouds: 16,000 - 43,000 feet (5,000 - 13,000 meters)

Middle Clouds: 7,000 - 23,000 feet (2,000 - 7,000 meters)

Low Clouds: Surface - 7,000 feet (surface - 2,000 meters)

Your Score is 75 points.

Instructions | Choose Level | Credits | Start Over

Sort Clouds by Composition

- Cirrostratus
- Altostratus
- Altostratus
- Cirrostratus
- Cirrus

Ice

Mix of Ice & Water

Water

Your Score is 100 points.

Instructions | Choose Level | Credits | Start Over

URL: scied.ucar.edu/cloud-sorting-game
El Niño Sorting Game

Sort It Out: El Niño or La Niña

- Jan 2013
- Jun 2001
- Dec 2010
- Oct 2007
- Dec 2002
- May 1997

El Niño warmer than normal water

- Jan 1998

La Nada neutral water temperature

- Nov 2003

La Niña cooler than normal water

- Feb 1999

Your Score is 75 points.

Can you tell El Niño from La Niña?

Credits
Start Over

Plans for a “Sort Molecules: Greenhouse Gas or non-GHG” version

URL: scied.ucar.edu/enso-sorting-game
Virtual Ballooning – Atmosphere Layers

URL: scied.ucar.edu/virtual-ballooning
Atmosphere Layers

URL: scied.ucar.edu/shortcontent/troposphere-overview
URL: scied.ucar.edu/shortcontent/stratosphere-overview
Compare Maps of Future Climate Projections

- Compare two different places, or
- Compare temperature vs. precipitation for same place

URL: scied.ucar.edu/compare-climates-regional-future-selector