Games & Simulations for Climate Education

Randy Russell
UCAR Center for Science Education

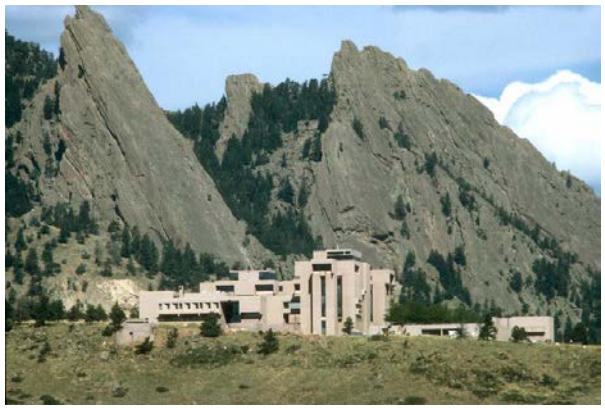
CLEAN Network Telecon
19 May 2015

National Center for Atmospheric Research

Boulder, CO

NCAR
NATIONAL CENTER FOR ATMOSPHERIC RESEARCH

UCAR
UNIVERSITY CORPORATION FOR ATMOSPHERIC RESEARCH



Some of our games originally developed for exhibit touchscreens

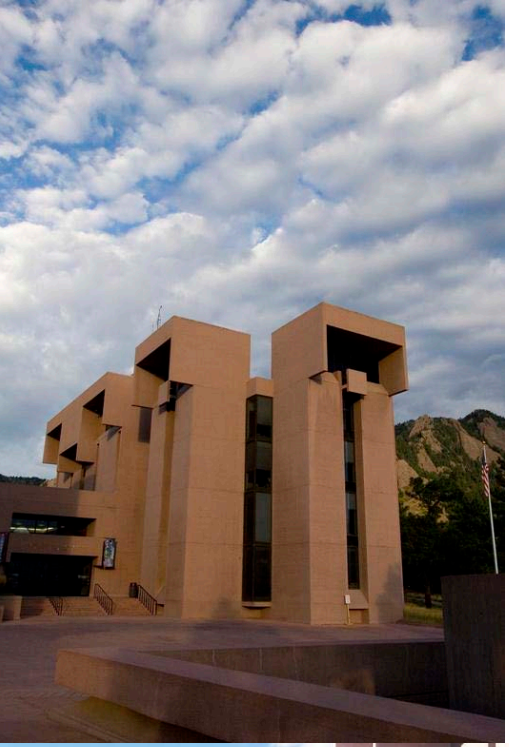


Exhibit Touchscreens

Similar to development for mobile touch devices (smartphones, tablets)

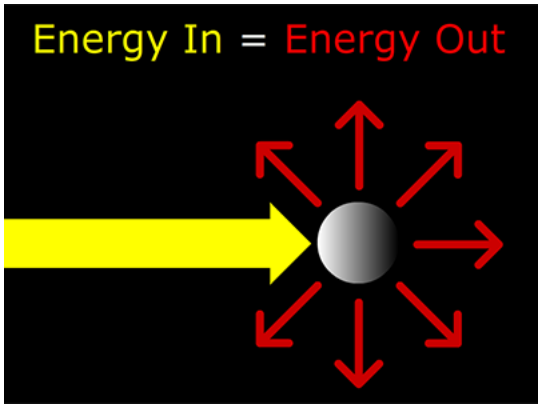
All models are wrong, but...

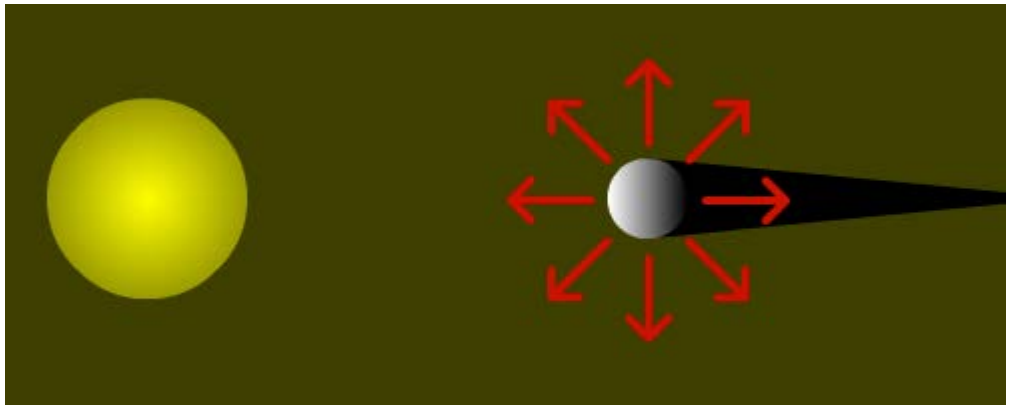
"Essentially, all models are wrong, but some models are useful."

- 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

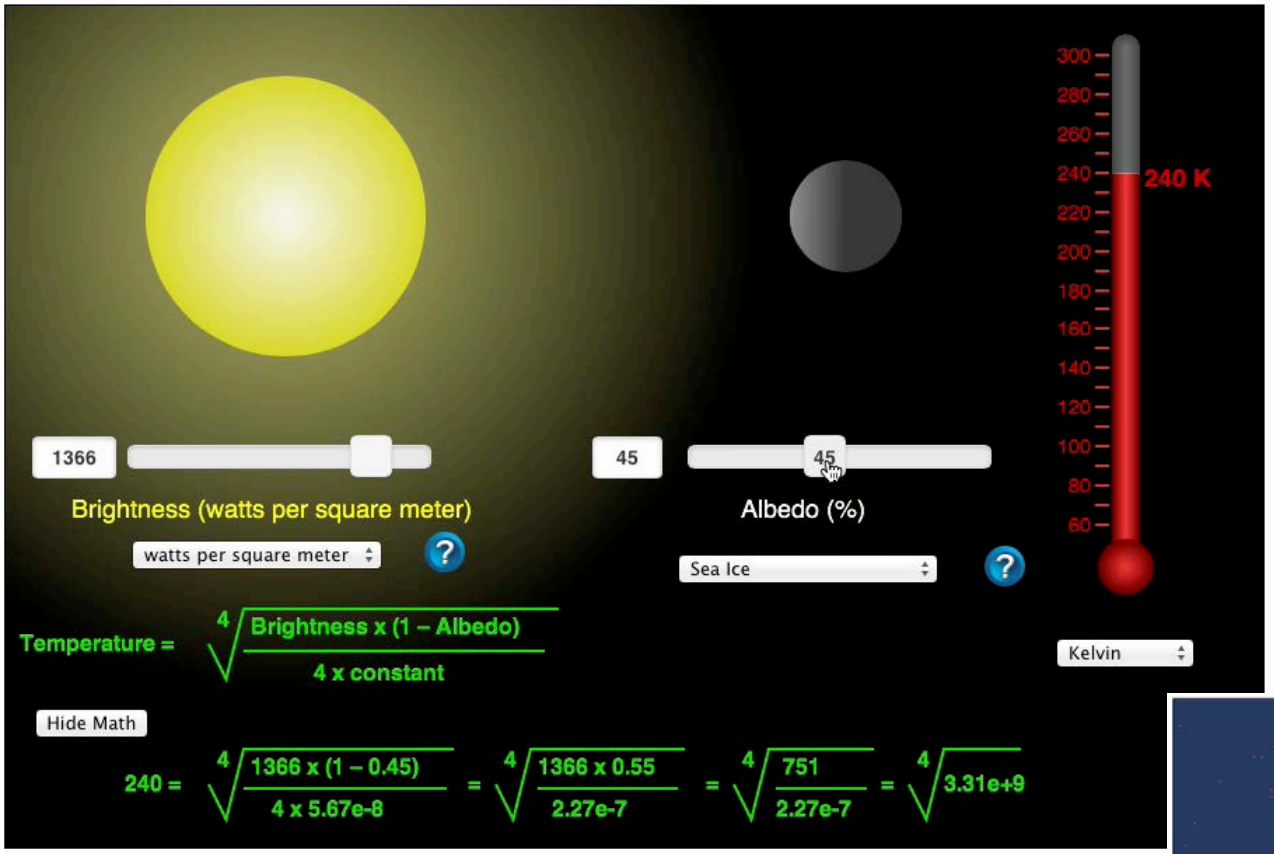


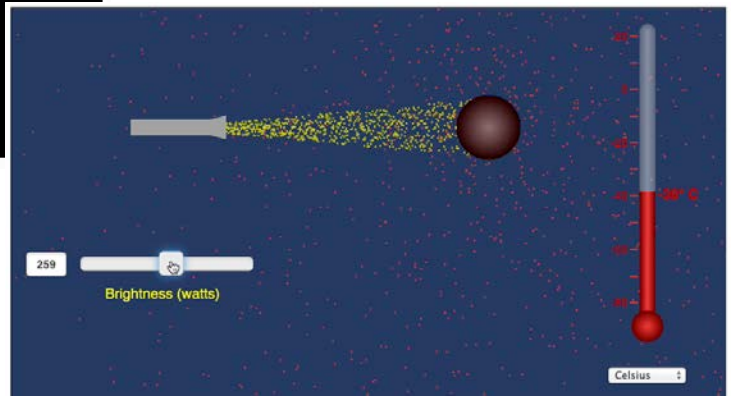


Science Topics

- Blackbody Radiator and the Stefan-Boltzman Law
- Conservation of Energy (Energy In = Energy Out)
- Albedo

Earth's Energy Balance





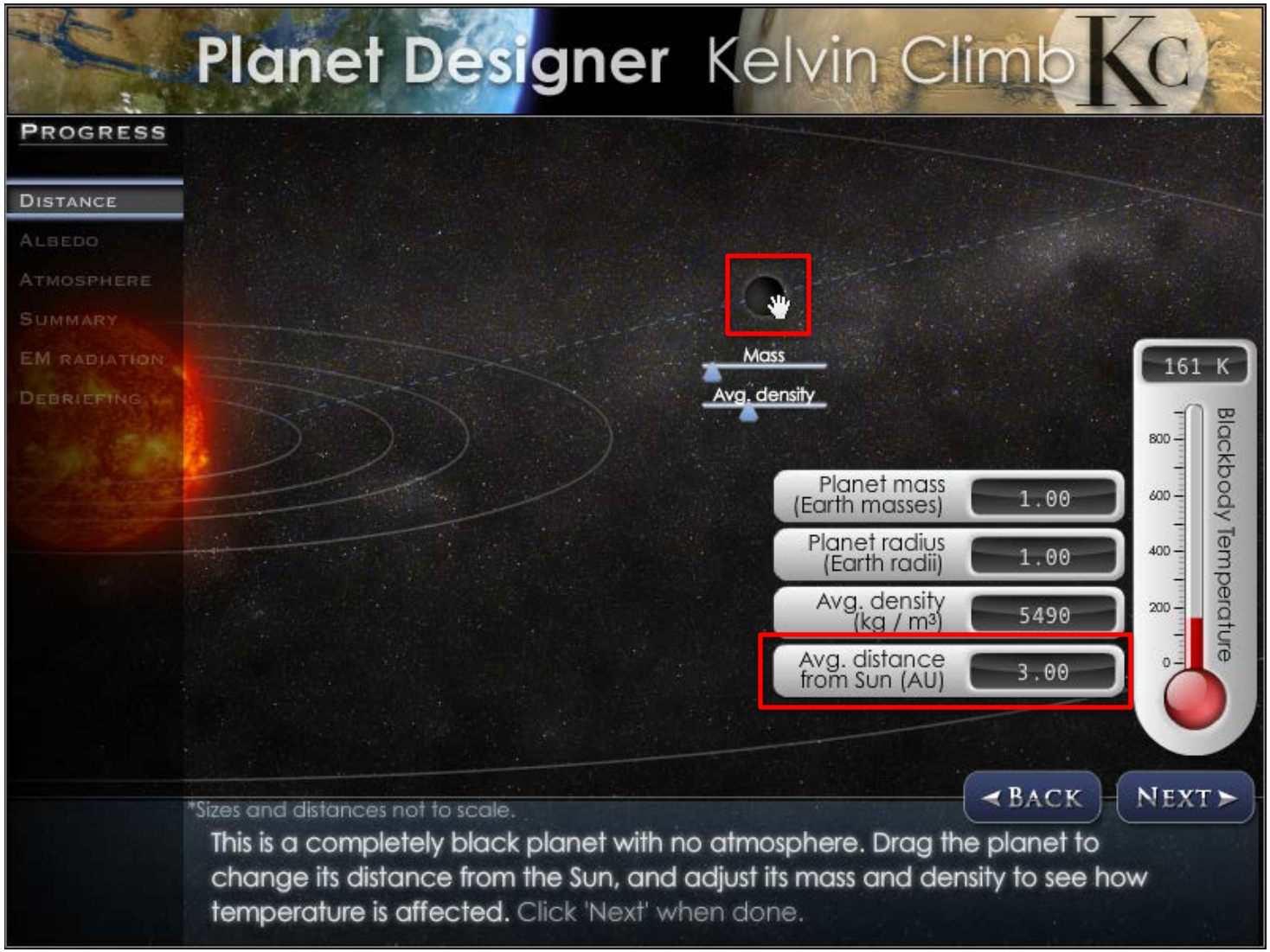
URL: scied.ucar.edu/earths-energy-balance

LASP: Kelvin Climb

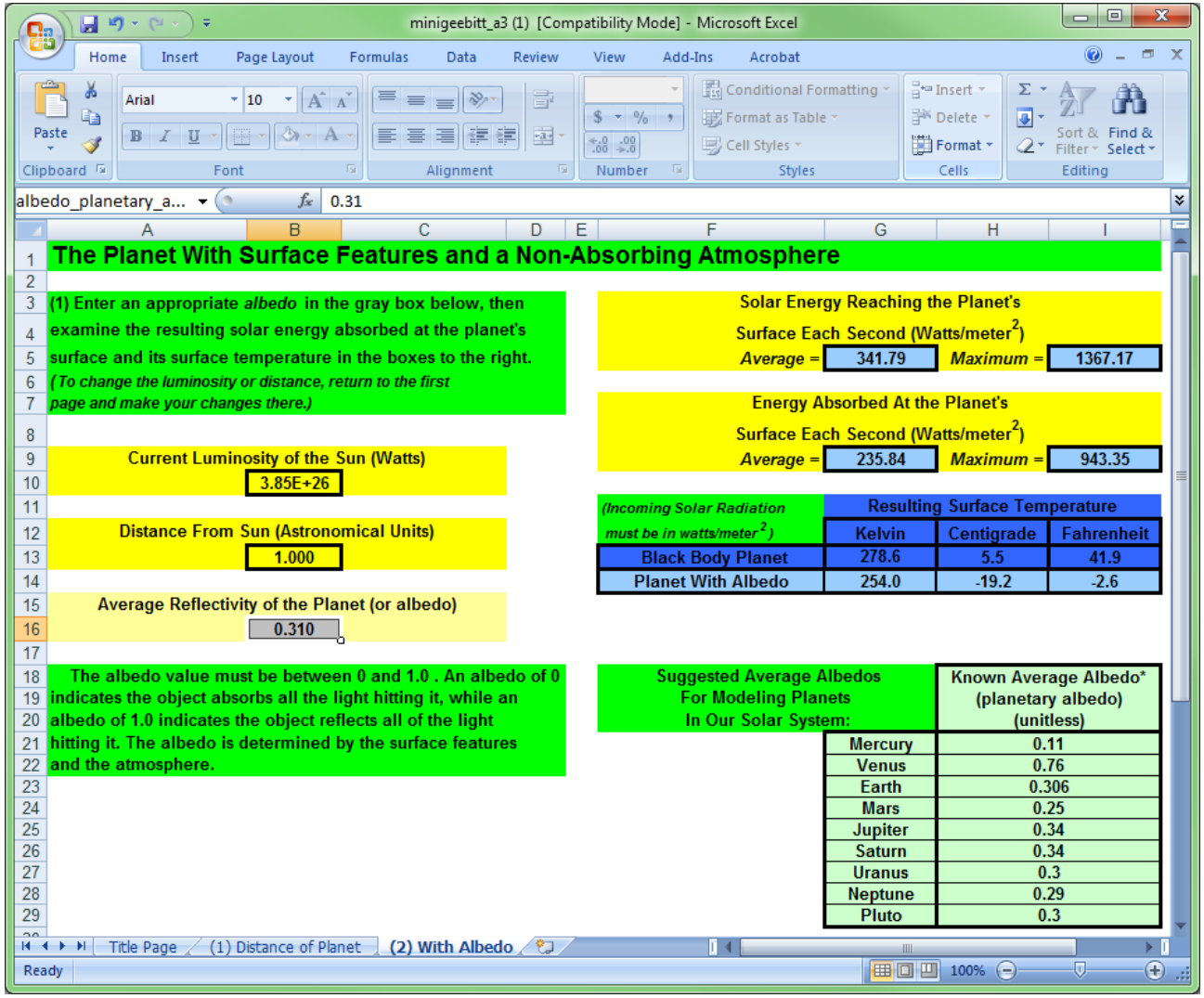
URL: lasp.colorado.edu/home/education/k-12/project-spectra/kelvin-climb-interactive

Add an Atmosphere with Greenhouse Gases

Change distance from Sun



NASA Spreadsheet: GEEBITT



minigeebitt_a3 (1) [Compatibility Mode] - Microsoft Excel

albedo_planetary_a... | 0.31

The Planet With Surface Features and a Non-Absorbing Atmosphere

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

Current Luminosity of the Sun (Watts): 3.85E+26

Distance From Sun (Astronomical Units): 1.000

Average Reflectivity of the Planet (or albedo): 0.310

The albedo value must be between 0 and 1.0 . An albedo of 0 indicates the object absorbs all the light hitting it, while an albedo of 1.0 indicates the object reflects all of the light hitting it. The albedo is determined by the surface features and the atmosphere.

Solar Energy Reaching the Planet's Surface Each Second (Watts/meter^2)
Average = 341.79 *Maximum* = 1367.17

Energy Absorbed At the Planet's Surface Each Second (Watts/meter^2)
Average = 235.84 *Maximum* = 943.35

(Incoming Solar Radiation must be in watts/meter^2)	Resulting Surface Temperature		
	Kelvin	Centigrade	Fahrenheit
Black Body Planet	278.6	5.5	41.9
Planet With Albedo	254.0	-19.2	-2.6

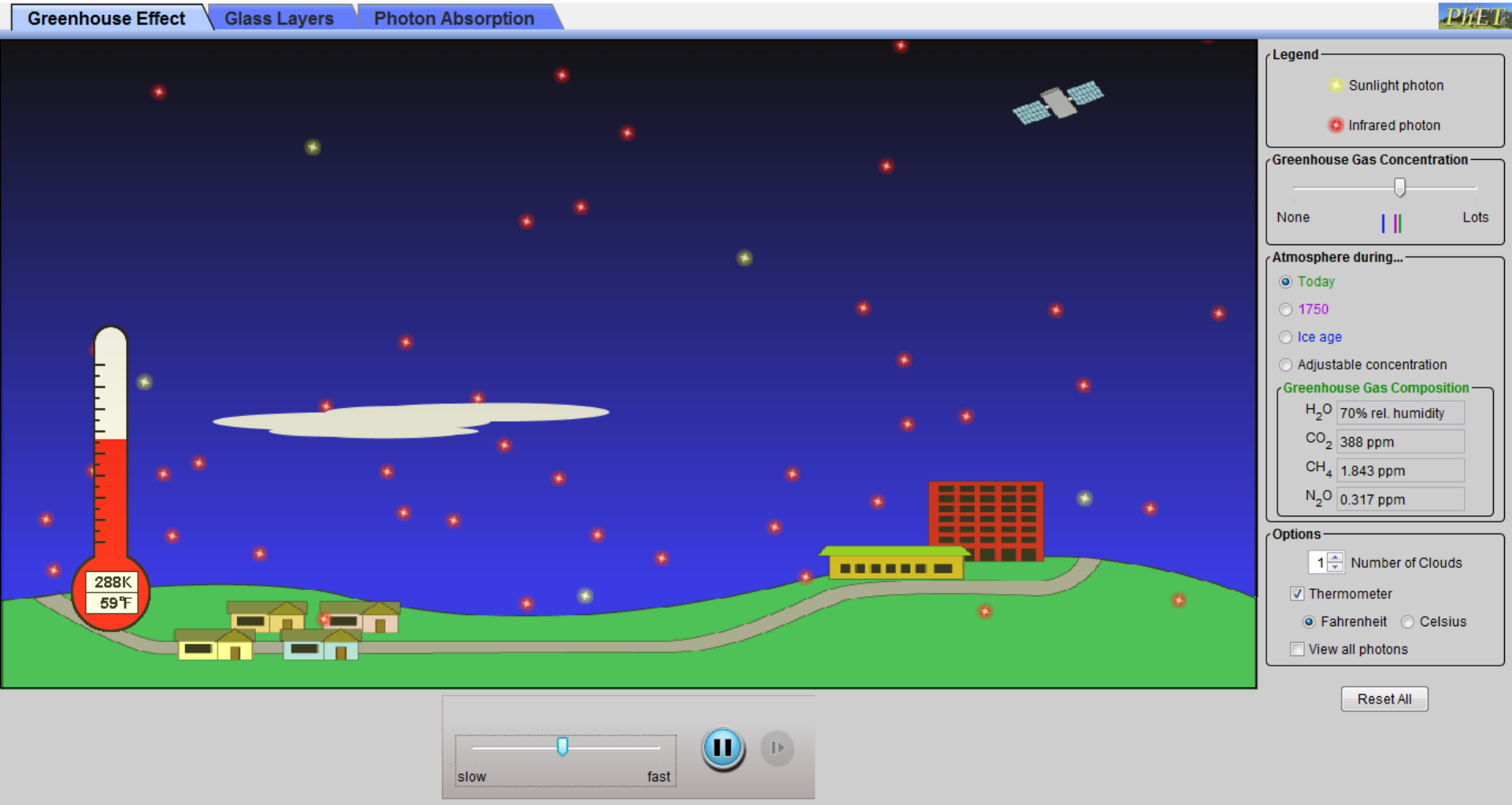
Suggested Average Albedos For Modeling Planets In Our Solar System:	Known Average Albedo* (planetary albedo) (unitless)
Mercury	0.11
Venus	0.76
Earth	0.306
Mars	0.25
Jupiter	0.34
Saturn	0.34
Uranus	0.3
Neptune	0.29
Pluto	0.3

Title Page | (1) Distance of Planet | (2) With Albedo

Ready

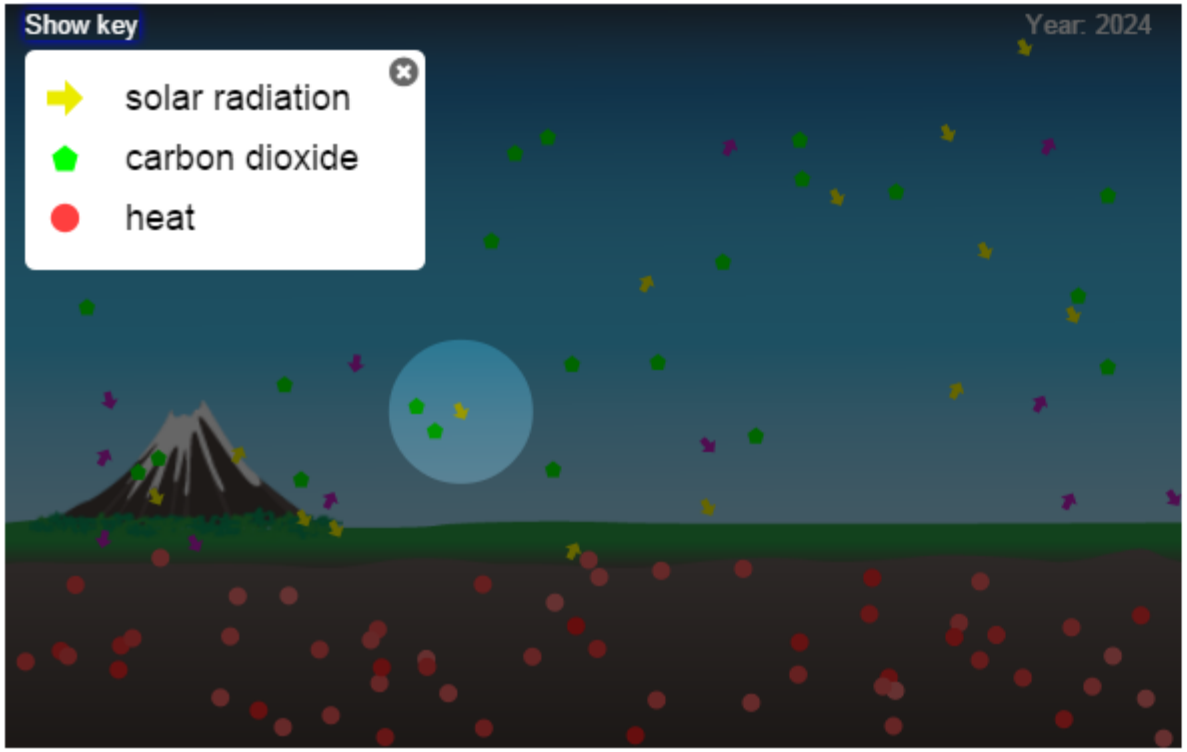
URL: icp.giss.nasa.gov/education/geebitt

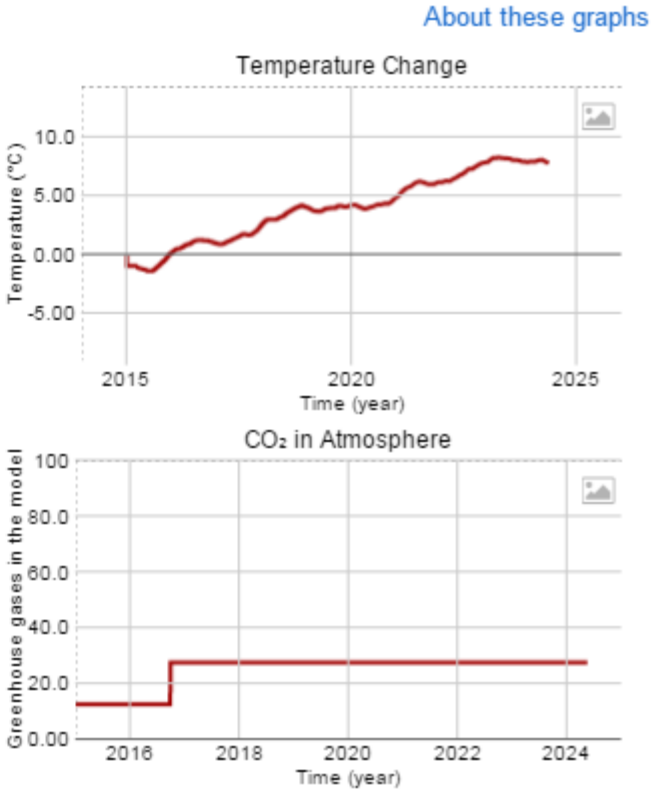
Greenhouse Effect - PhET



URL: phet.colorado.edu/en/simulation/greenhouse

Greenhouse Effect – Concord Consortium





Erupt! Remove CO_2

Stop following Follow CO2

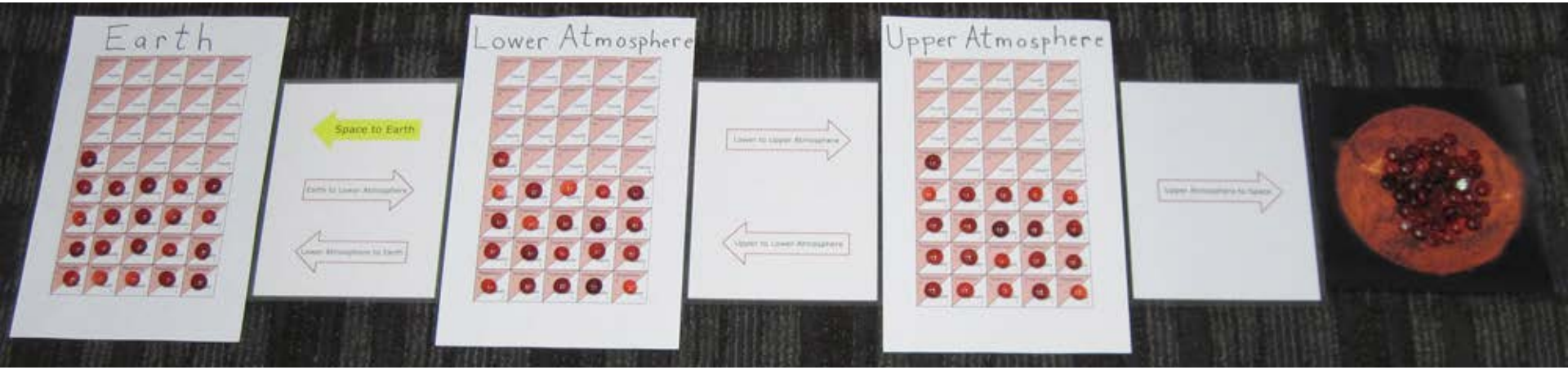
Show: Gases Rays Heat

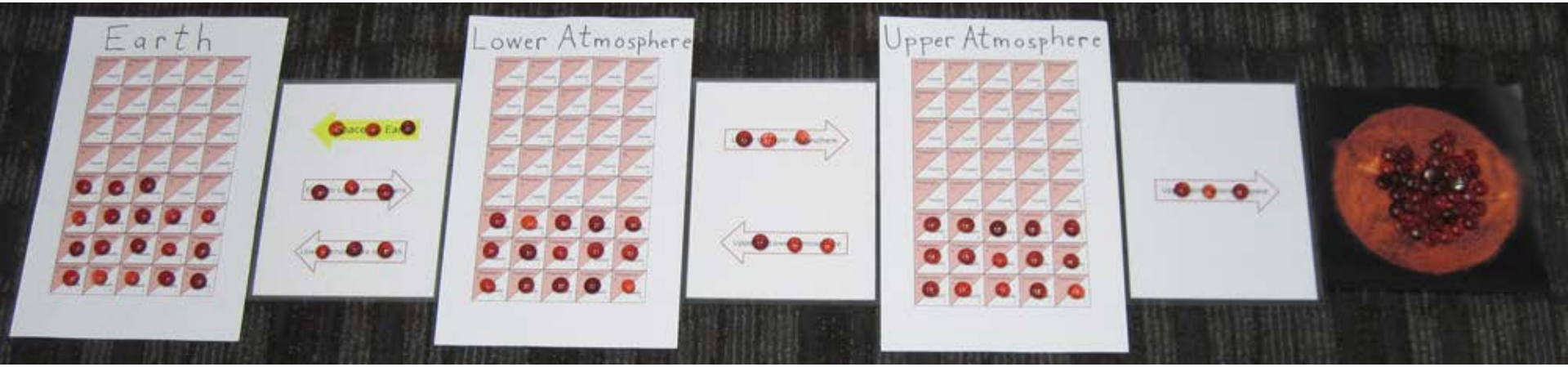
What is the future of Earth's Climate? module

URL: concord.org/stem-resources/what-future-earths-climate

URL: authoring.concord.org/activities/279/pages/1736/c05ea8e7-f131-447d-8b68-ef31c4d2206b

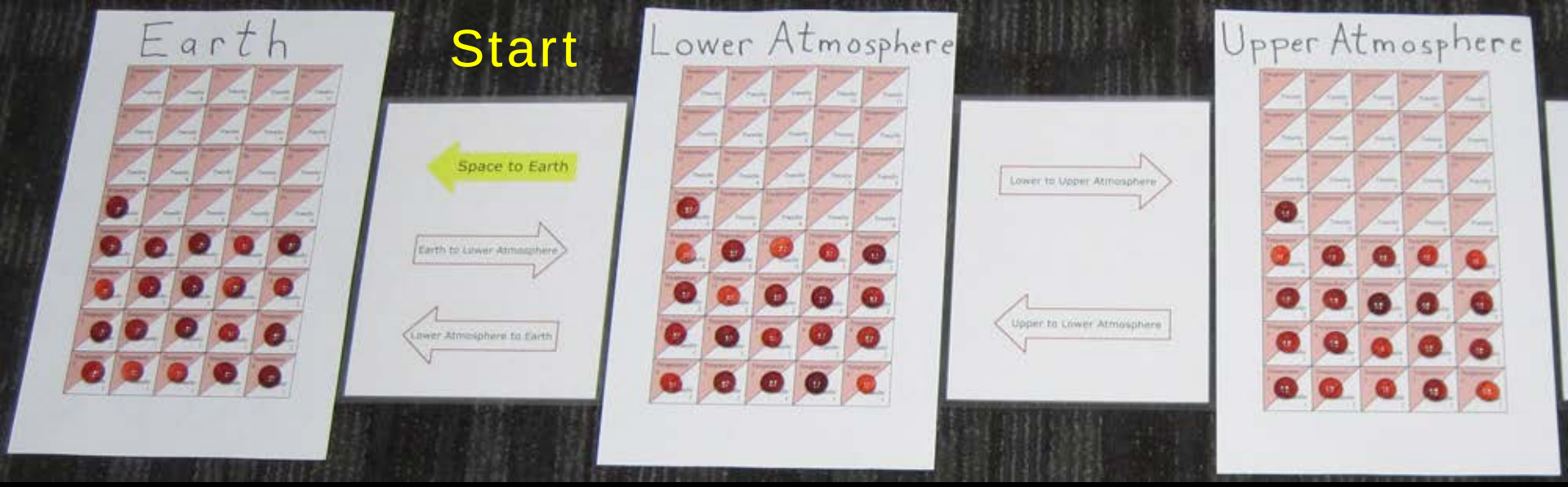
Greenhouse Effect – Little Shop of Physics

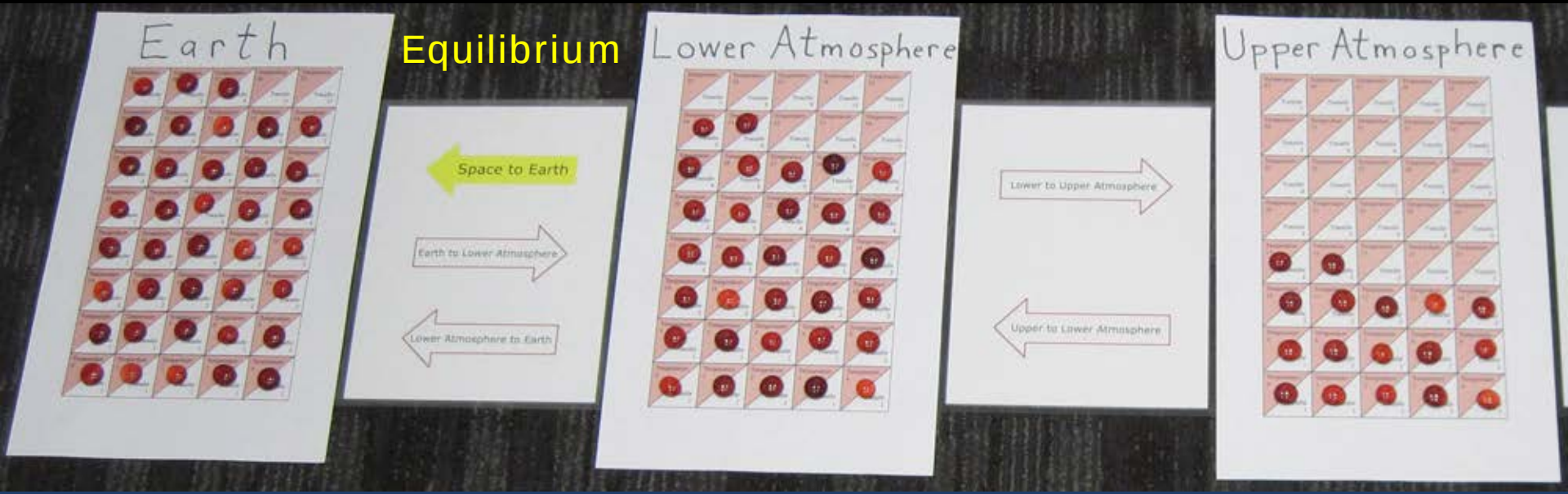




What is a “model”? activity

URL: littleshop.physics.colostate.edu/activities/atmos1/WhatIsAModel.pdf


Start
Earth
Space to Earth
Earth to Lower Atmosphere
Lower Atmosphere to Earth
Lower Atmosphere
Lower to Upper Atmosphere
Upper to Lower Atmosphere
Upper Atmosphere

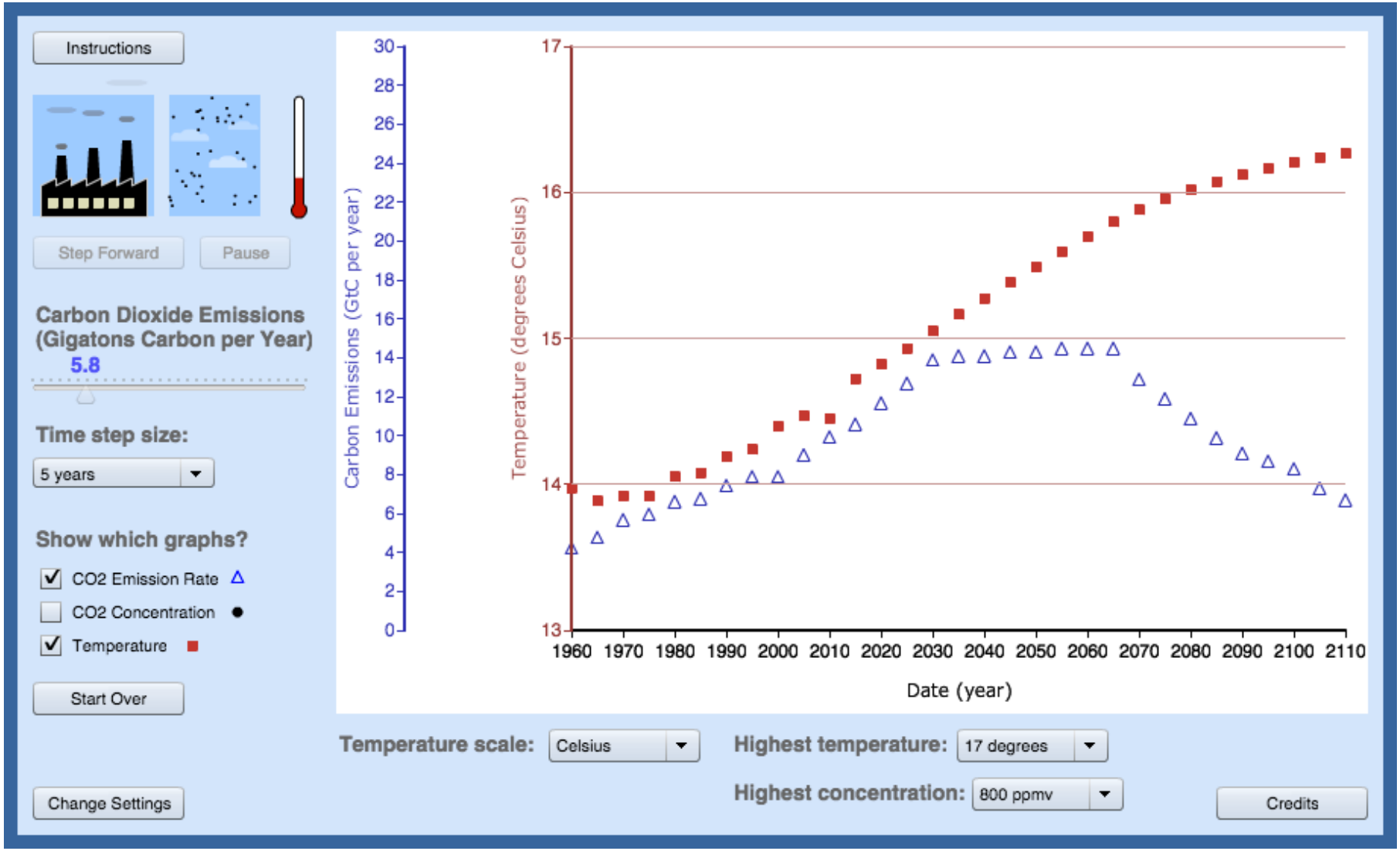

Equilibrium
Earth
Space to Earth
Earth to Lower Atmosphere
Lower Atmosphere to Earth
Lower Atmosphere
Lower to Upper Atmosphere
Upper to Lower Atmosphere
Upper Atmosphere

URL: monash.edu/research/simple-climate-model/mscm/index.html

Columbia University - EdGCM

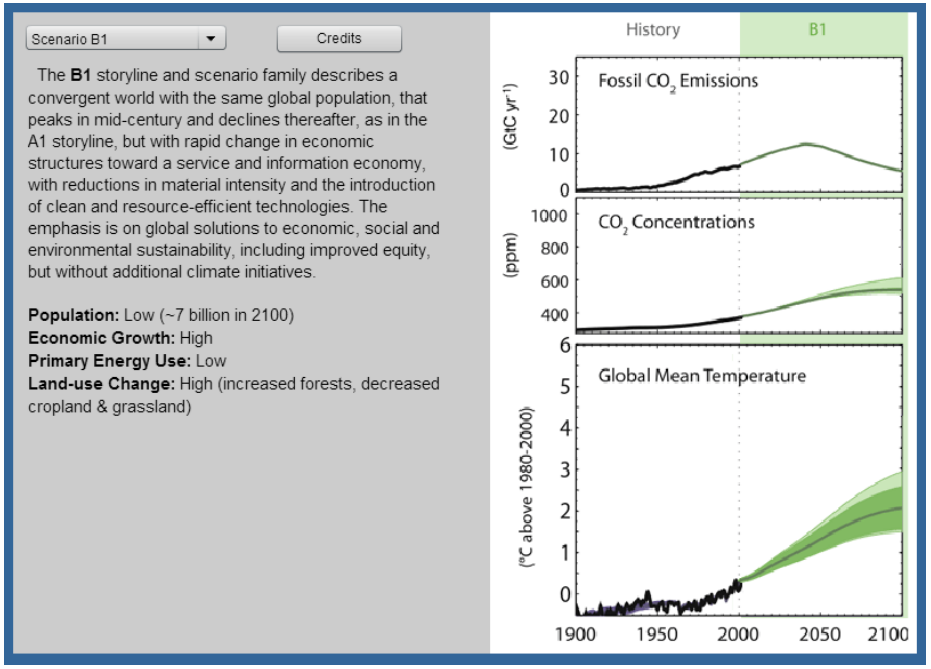
URL: edgcm.columbia.edu

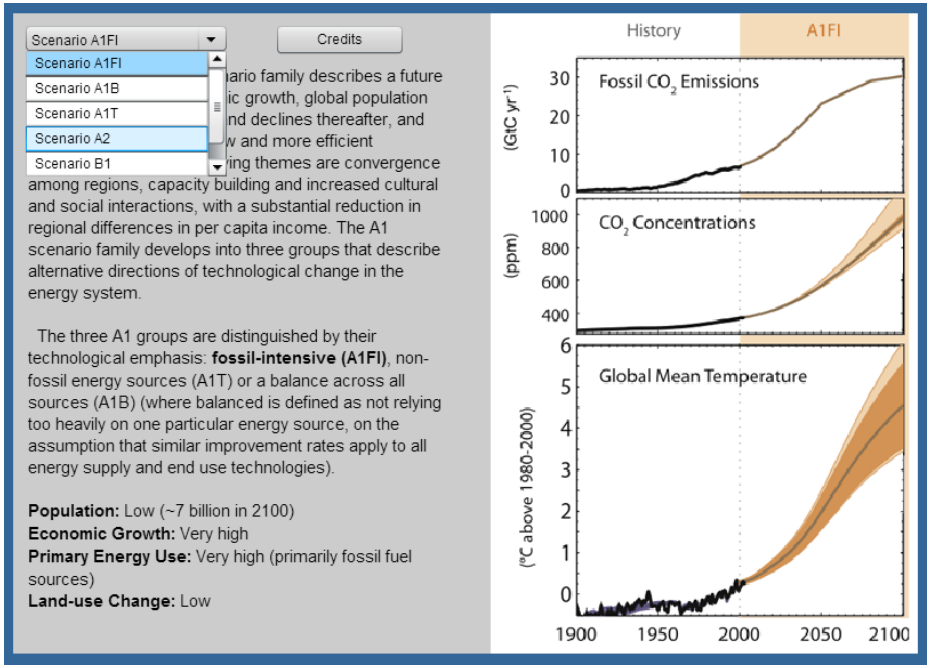
Very, Very Simple Climate Model



URL: scied.ucar.edu/simple-climate-model

Compare Graphs of IPCC Scenarios

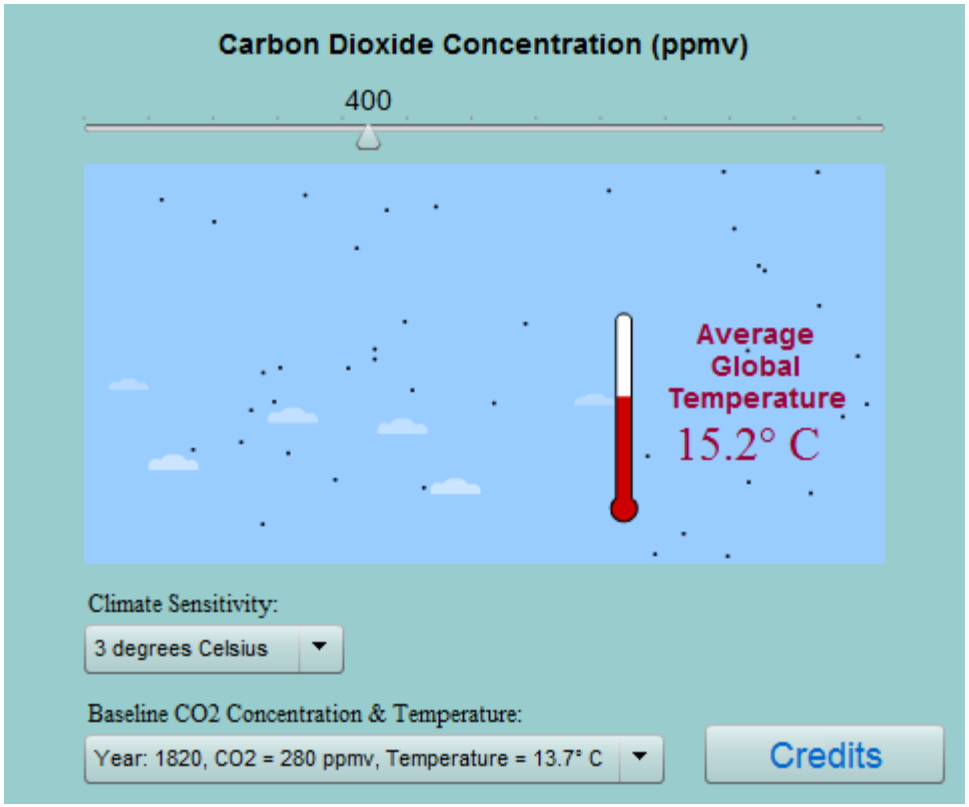


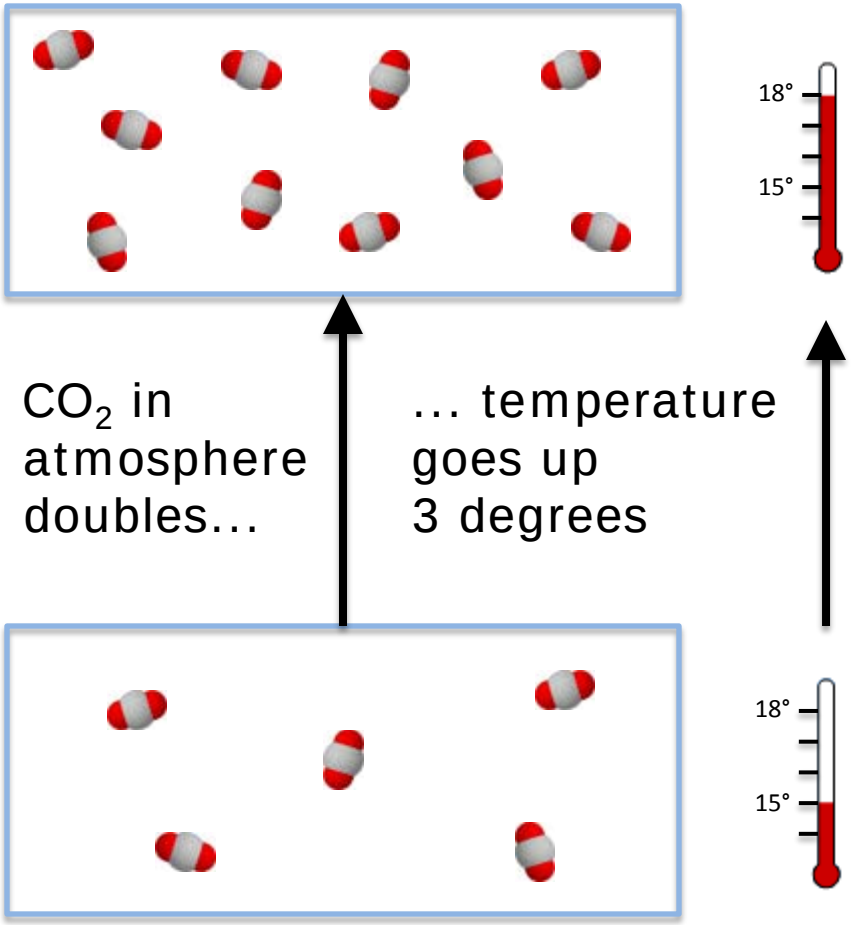


Version for 5th Assessment Report under development

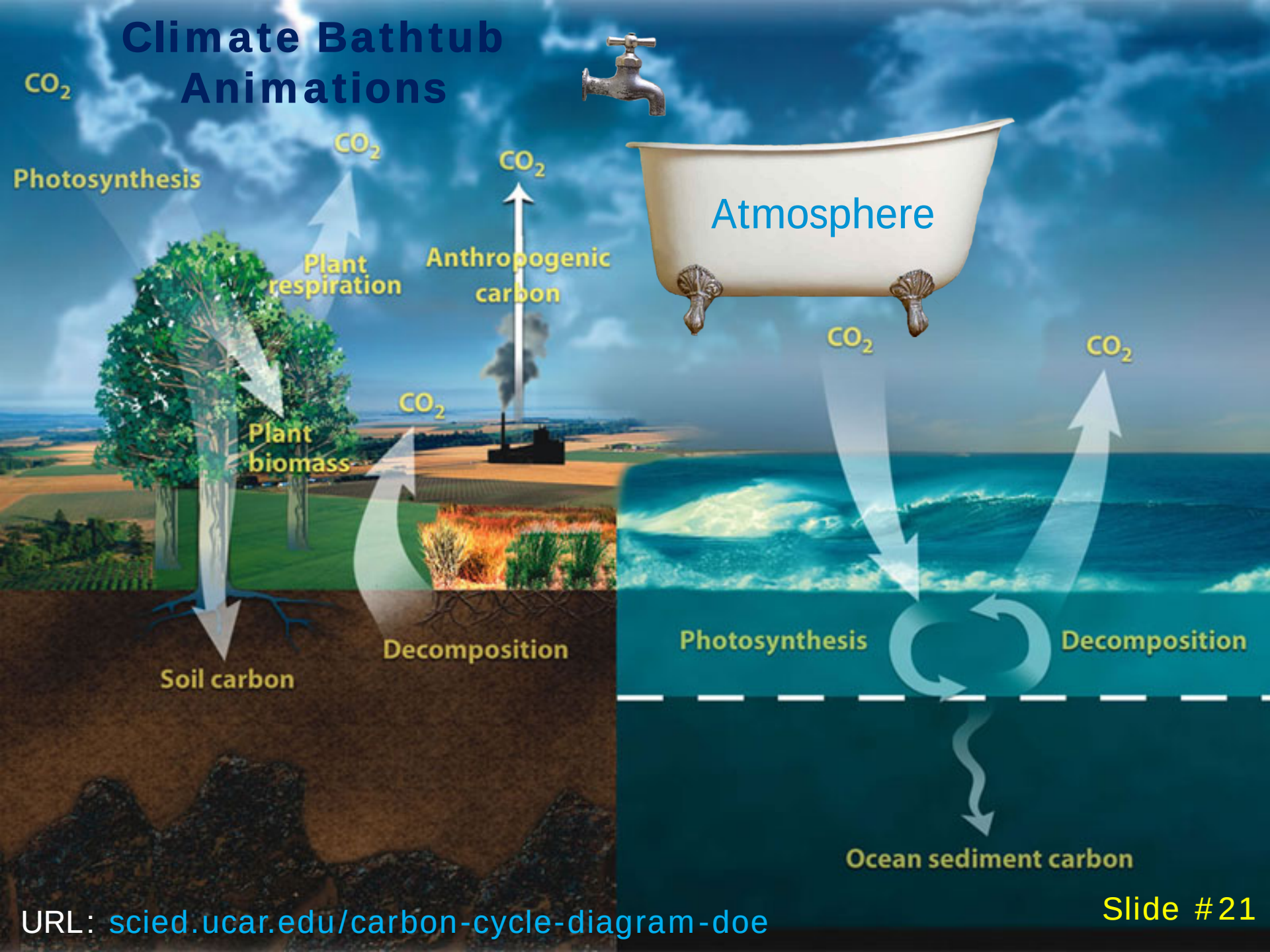
URL: scied.ucar.edu/compare-ipcc-scenarios-interactive

Climate Sensitivity Calculator

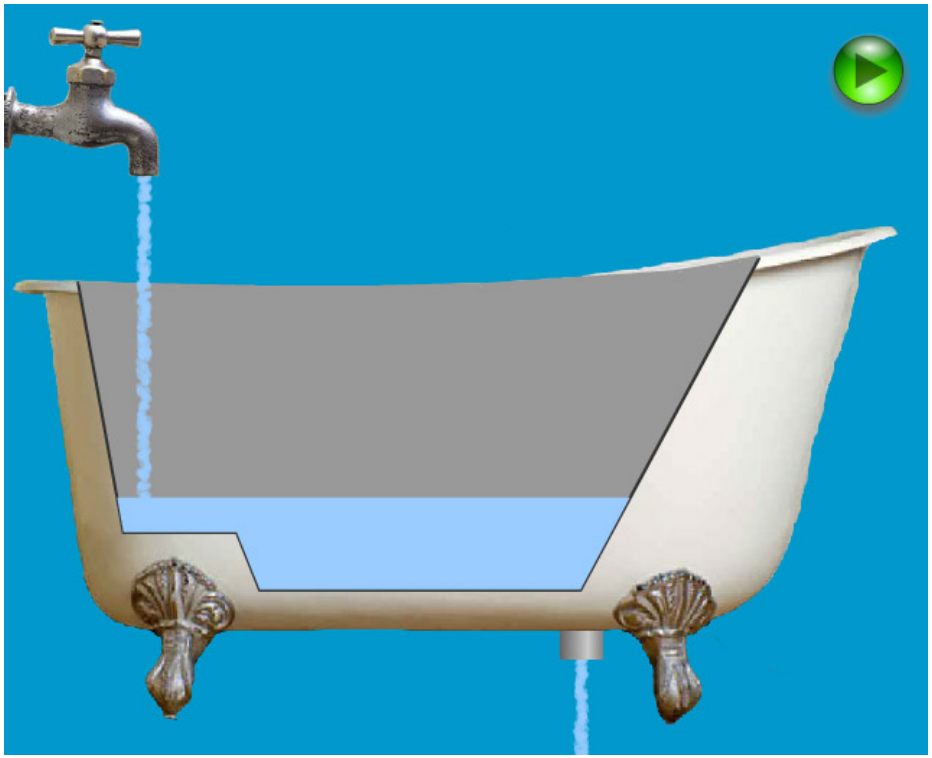


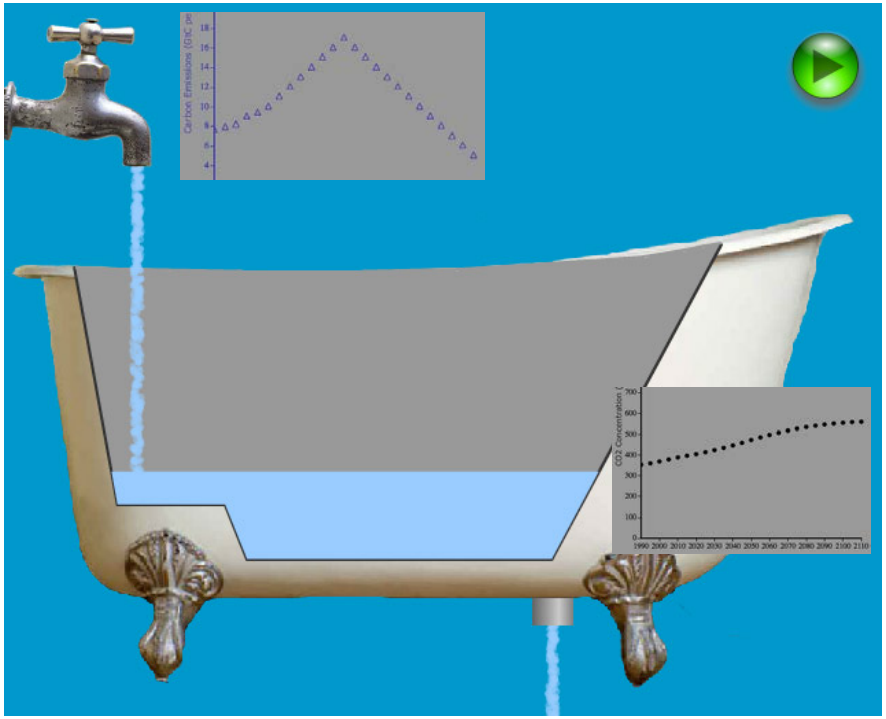


URL: scied.ucar.edu/climate-sensitivity-calculator


Climate Bathtub Animations
CO_2
Photosynthesis
CO_2
Plant respiration
CO_2
Anthropogenic carbon
Atmosphere
CO_2
CO_2
Plant biomass
Soil carbon
Decomposition
Photosynthesis
Decomposition
Ocean sediment carbon
URL: scied.ucar.edu/carbon-cycle-diagram-doe
Slide #21

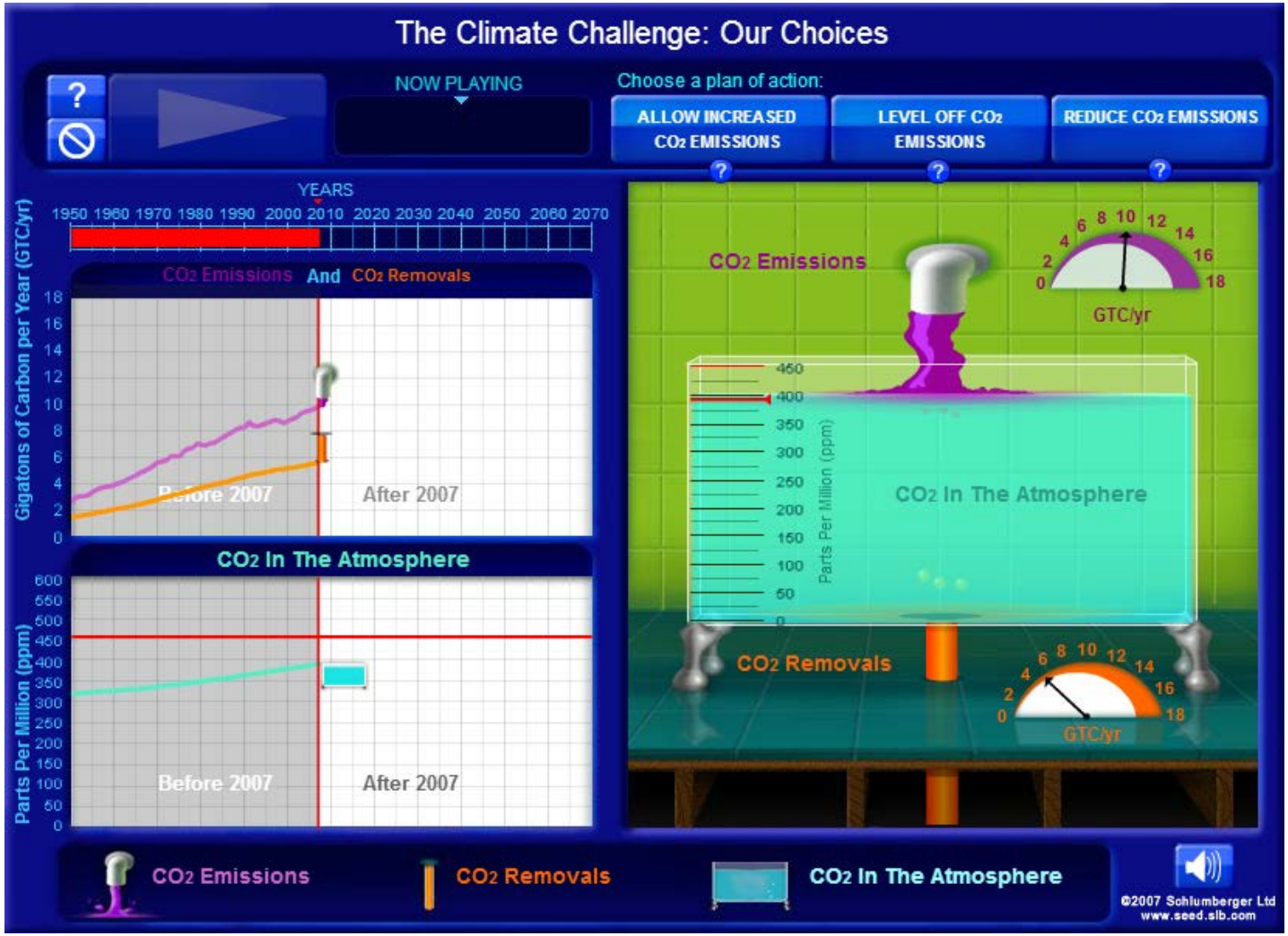
Climate Bathtub Animations





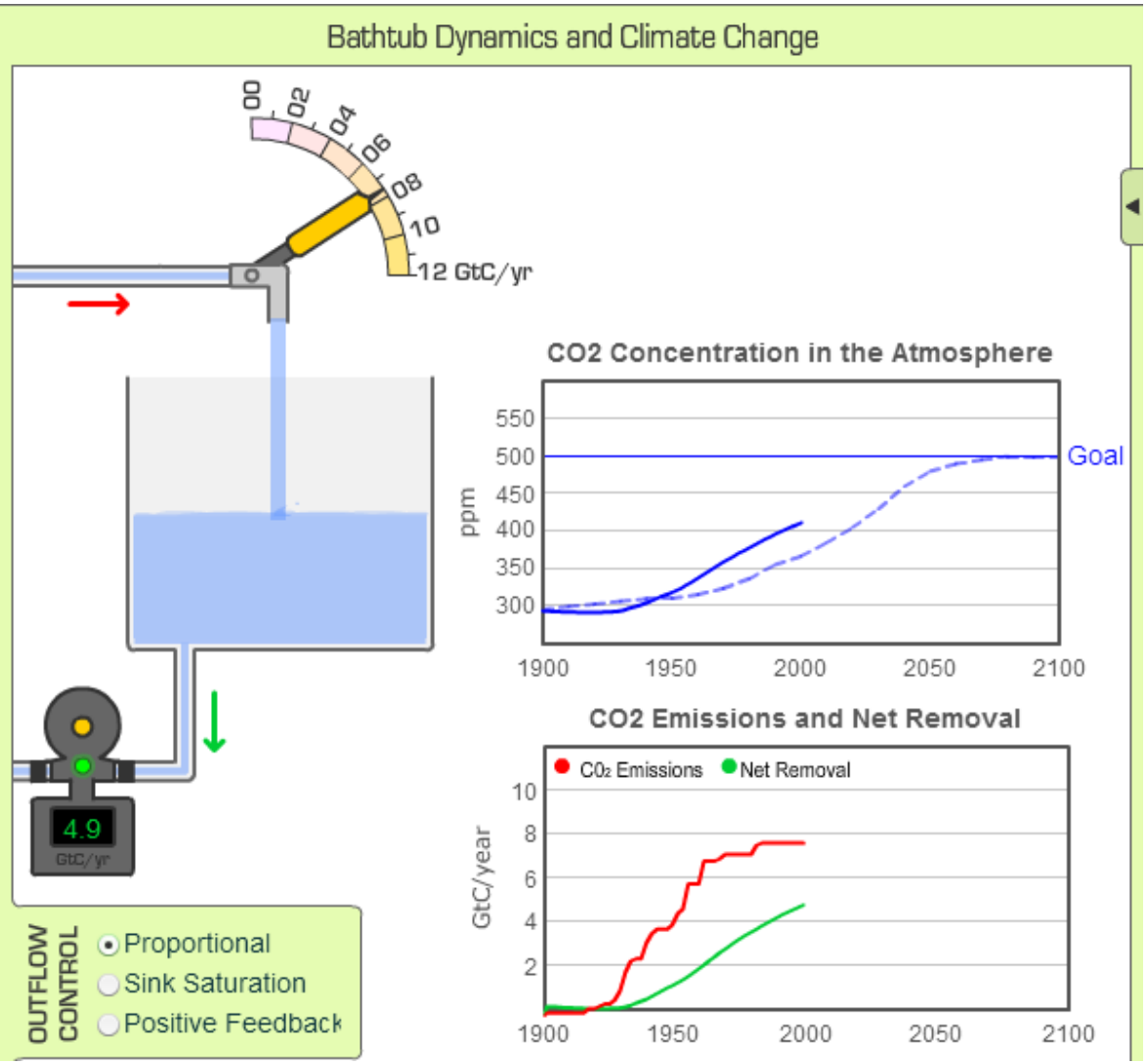
URL: scied.ucar.edu/climate-bathtub-model-animations

Climate Interactive – Climate Bathtub Simulation



URL: www.climateinteractive.org/tools/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/

Ruler of the World

Introduction | Petroleum | Coal | Natural Gas | Nuclear | Hydro | Biofuels | Wind | Solar | Geothermal | Help | Results

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 pettawatt-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 natura its 200 kilograms of carbon dioxide for every megawatt-hour of energy produced.

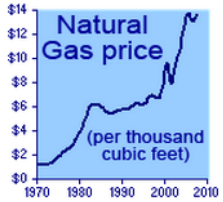
It is reasonable to assume that natura ts 3 cents per kilowatt-hour of energy produced.

The impact on the environment cause use of natural gas is Slightly Bad.

The public, businesses, and/or governr Somewhat Support use of natural gas.

150
140
130
120
110
100
90
80
70
60
55
50
45
40
35
30
25
20
15
10

- Natural Gas Overview
- Amount of Energy from Natural Gas
- Carbon Dioxide Emissions
- Cost of Natural Gas



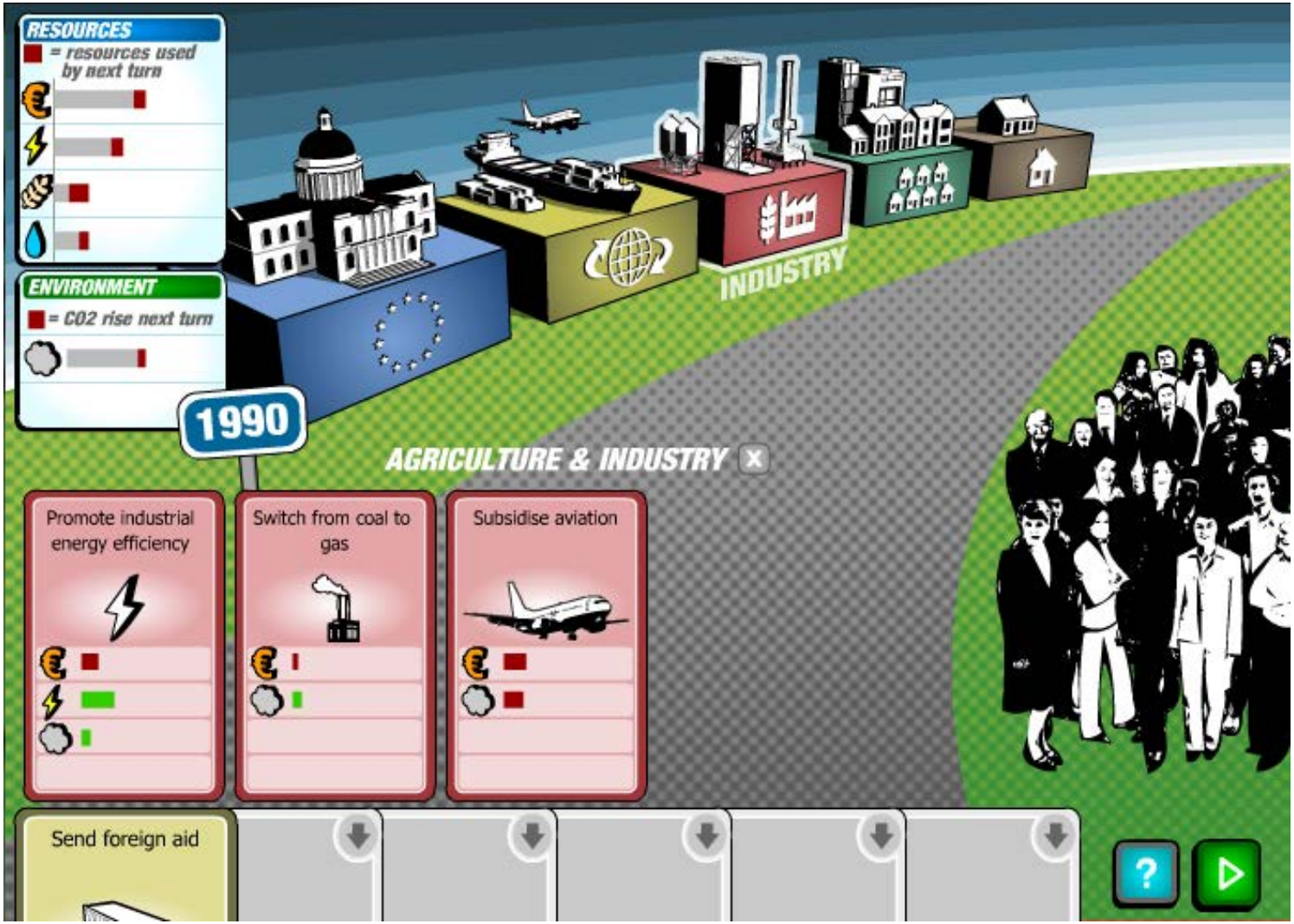
Natural gas costs about $14 per thousand cubic feet sold to residential customers. That works out to about 4.7 cents per kilowatt-hour of energy produced. When used to generate electricity (instead of for heating), natural gas costs about 3.7 cents per kWh of electricity delivered to customers.

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.

- Environmental Impacts of Natural Gas
- Support for or Resistance to Natural Gas?

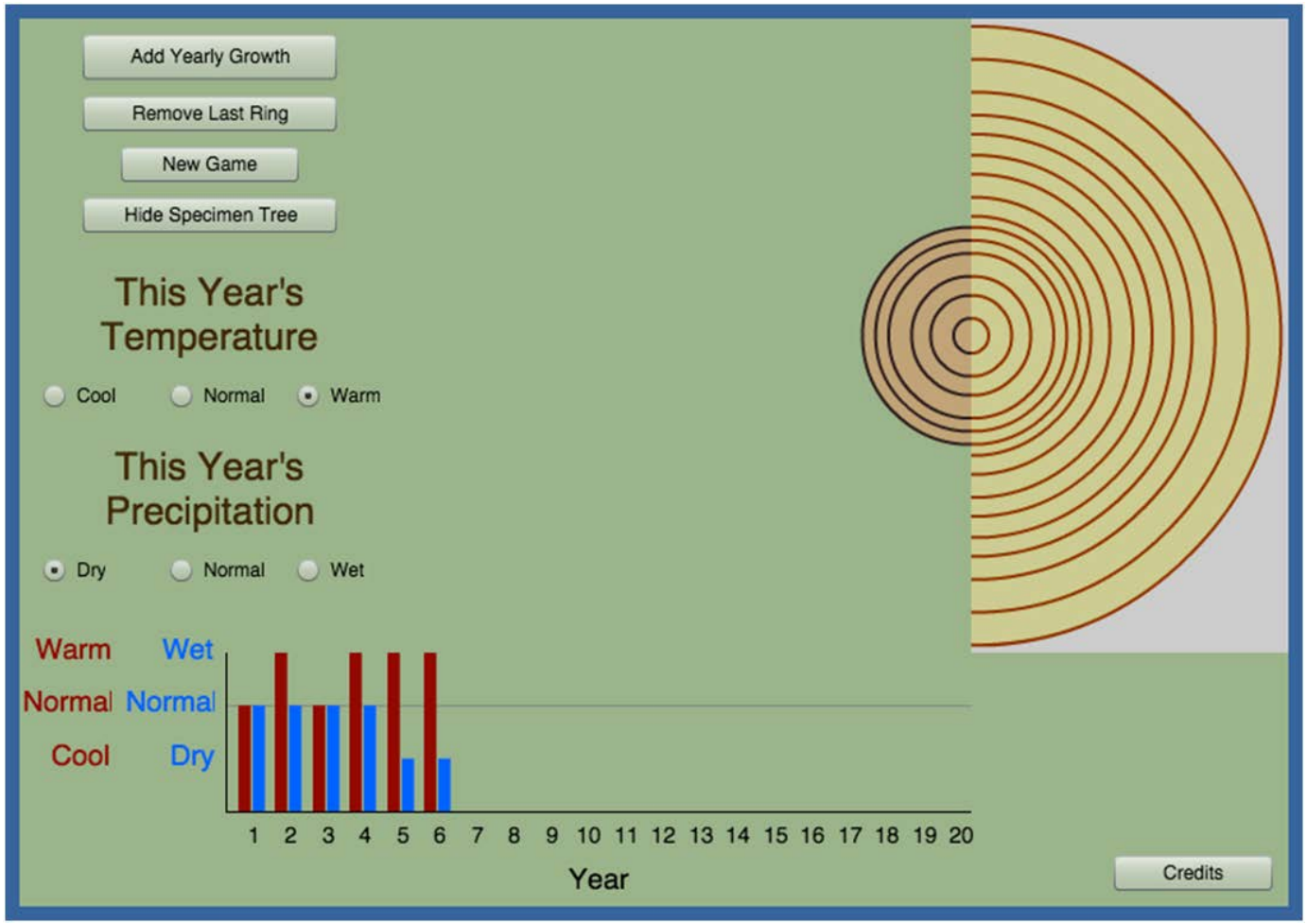
URL: scied.ucar.edu/ruler-world

BBC Climate Challenge



URL: www.bbc.co.uk/sn/hottopics/climatechange/climate_challenge

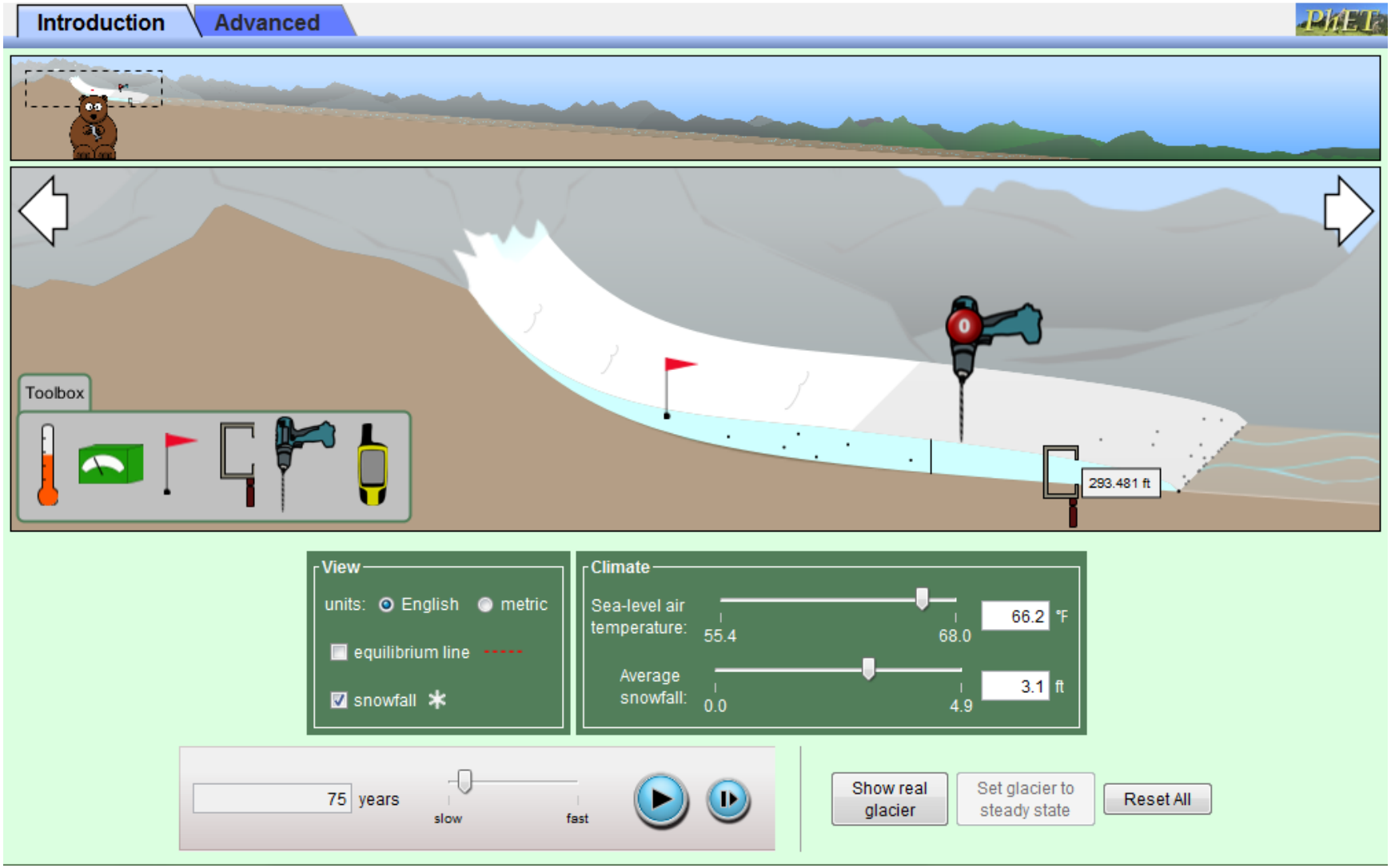
Tree Rings - Dendrochronology



Hoping to make a suite of paleoclimate sims; ice cores, sea sediments, etc.

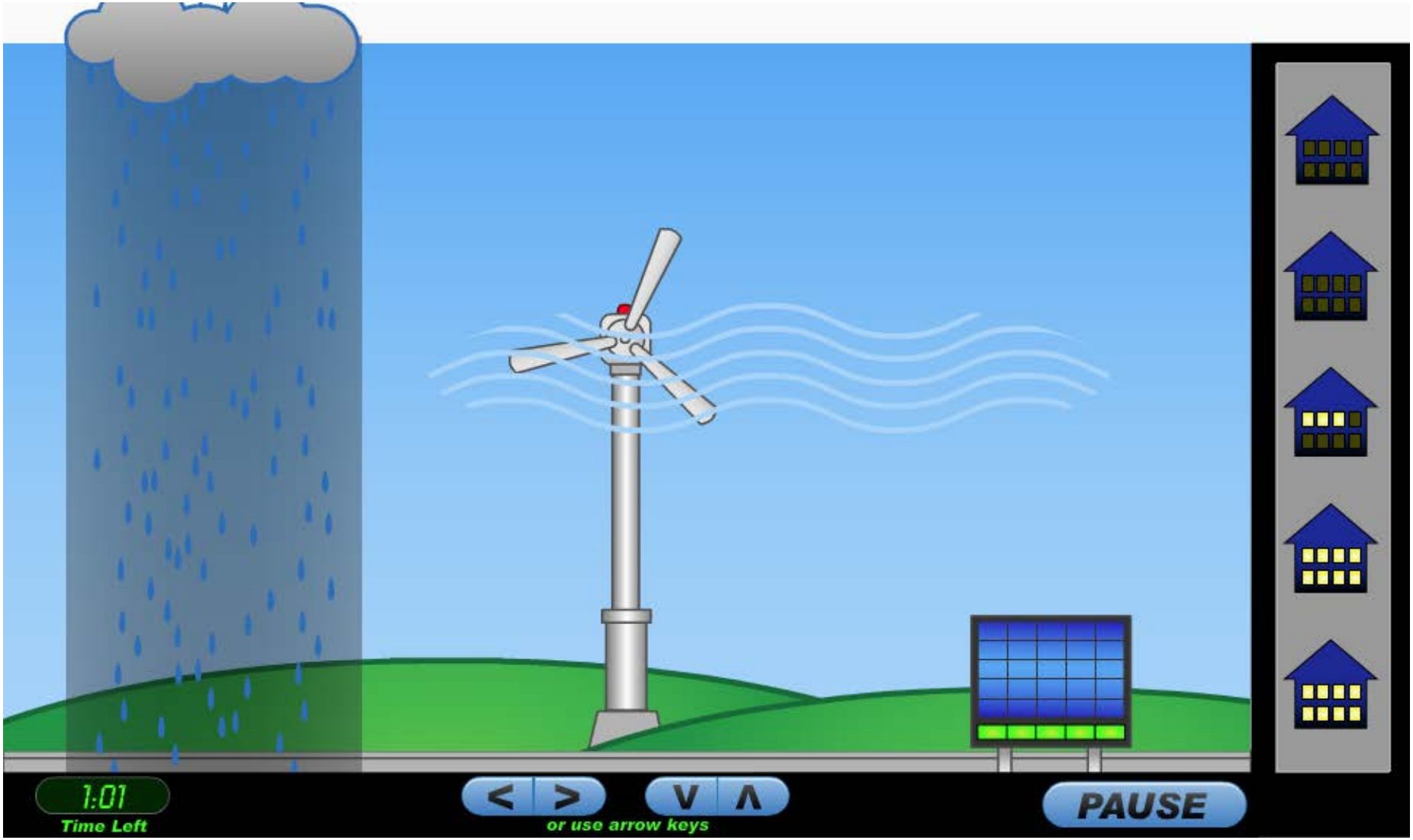
URL: scied.ucar.edu/tree-ring-interactive

Glacier Model - PhET



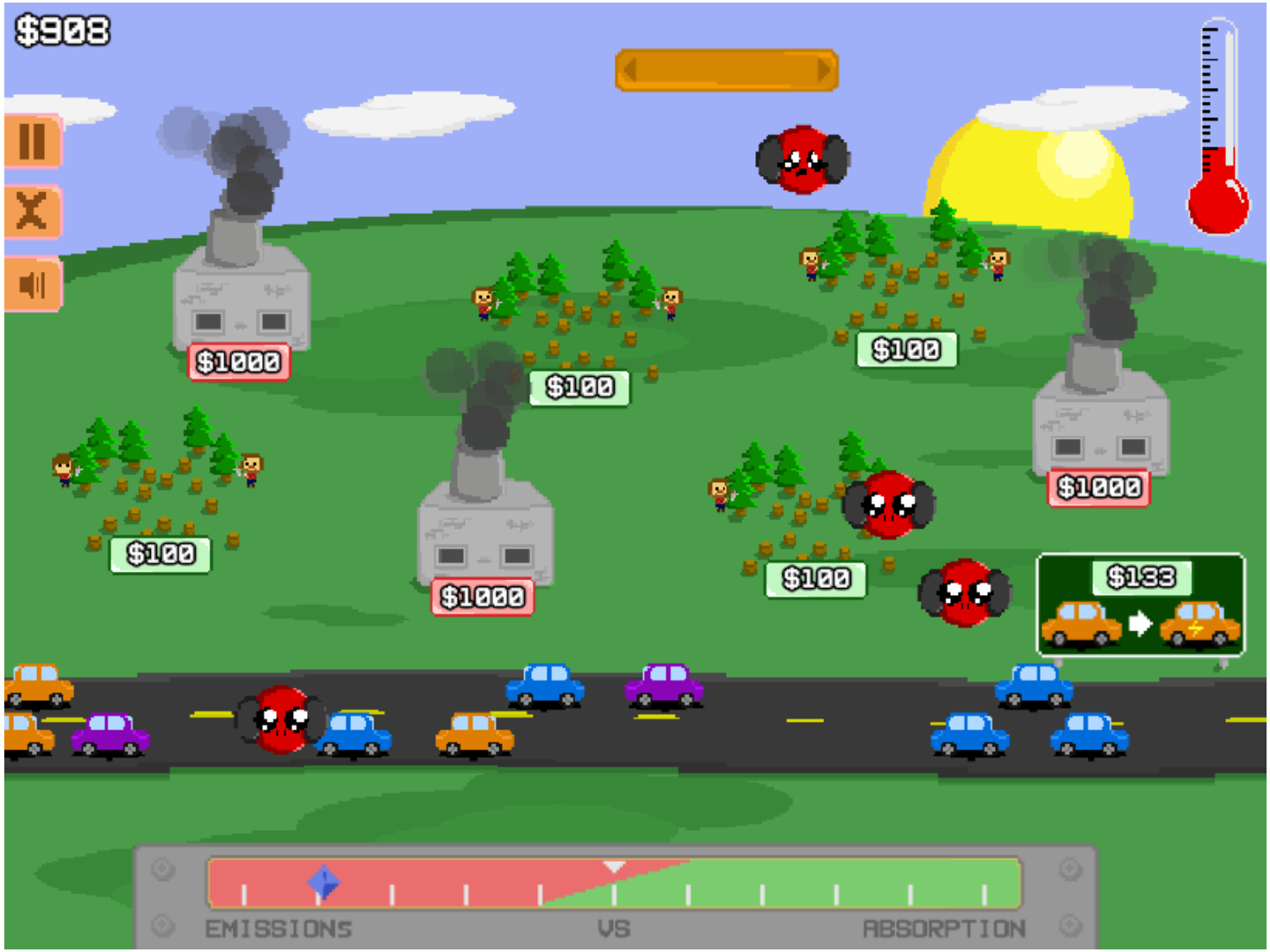
URL: phet.colorado.edu/en/simulation/glaciers

NASA's Climate Kids –Power Up!



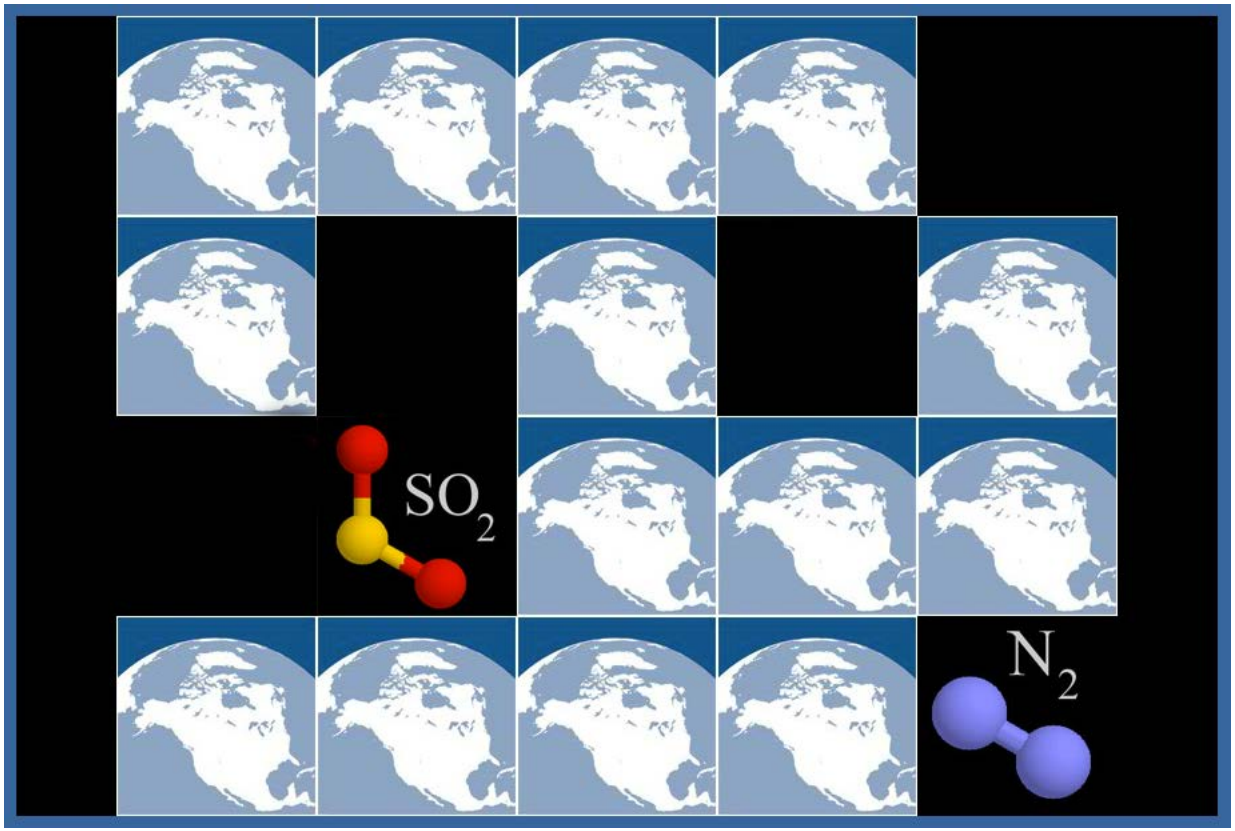
URL: climatekids.nasa.gov/power-up

NASA's Climate Kids – OFFSET!

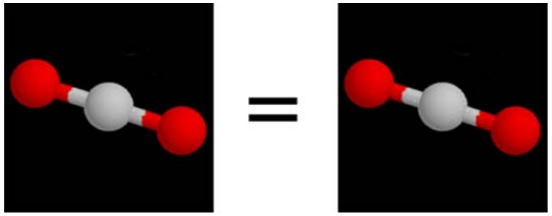


URL: climatekids.nasa.gov/offset

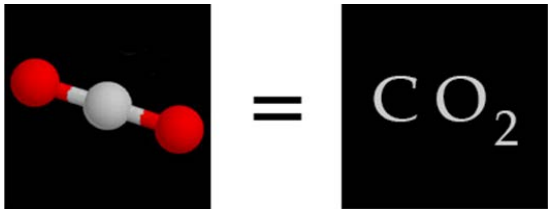
Atmospheric Chemistry Memory Game



Easy Level



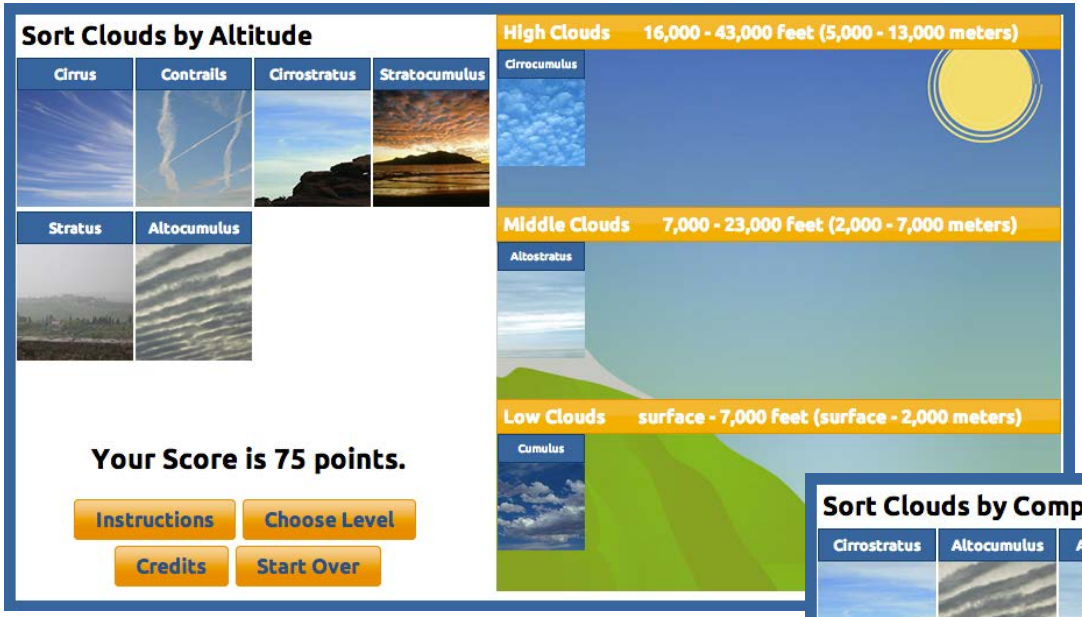
Advanced Level

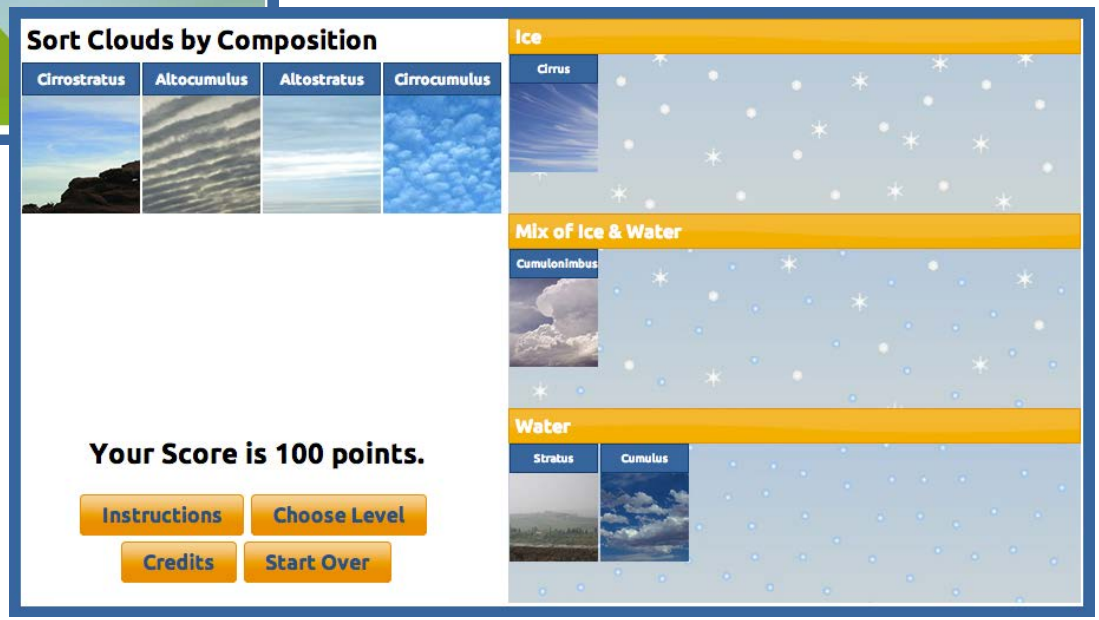


Includes the GHGs carbon dioxide and methane
Advanced level: compare equivalent, not identical, representations

URL: scied.ucar.edu/molecules-memory-game

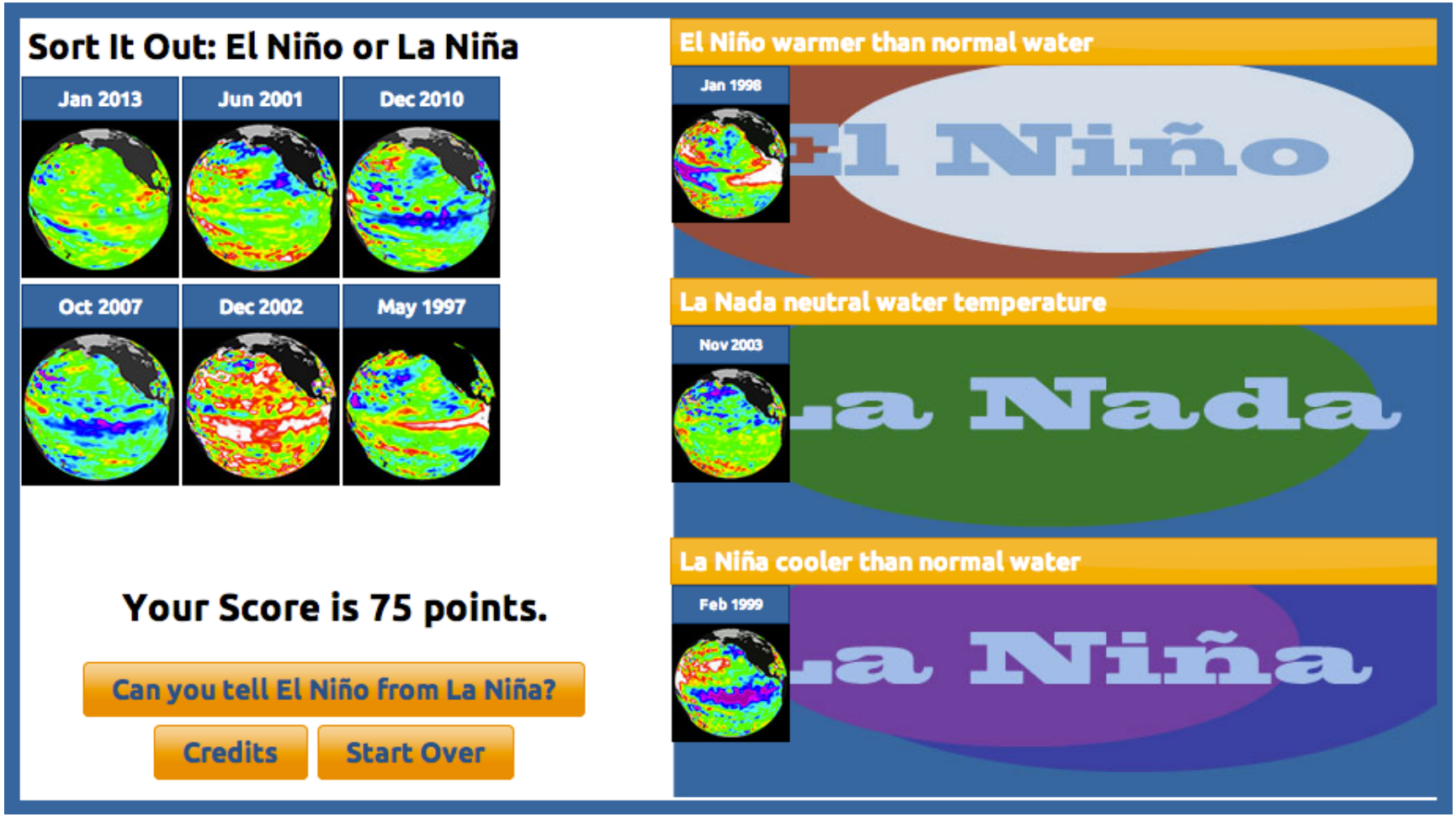
Cloud Sorting Game





URL: scied.ucar.edu/cloud-sorting-game

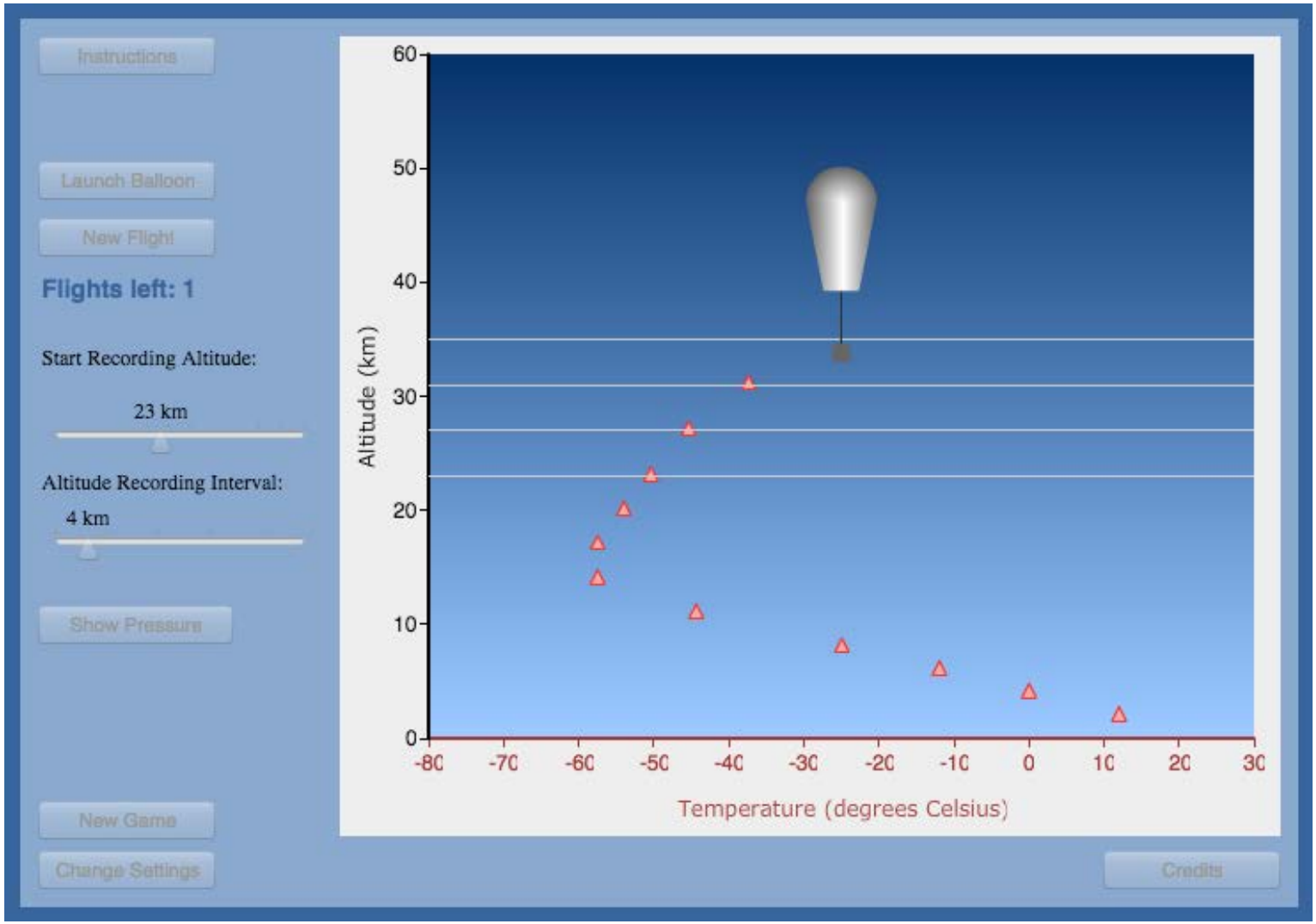
El Niño Sorting Game



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

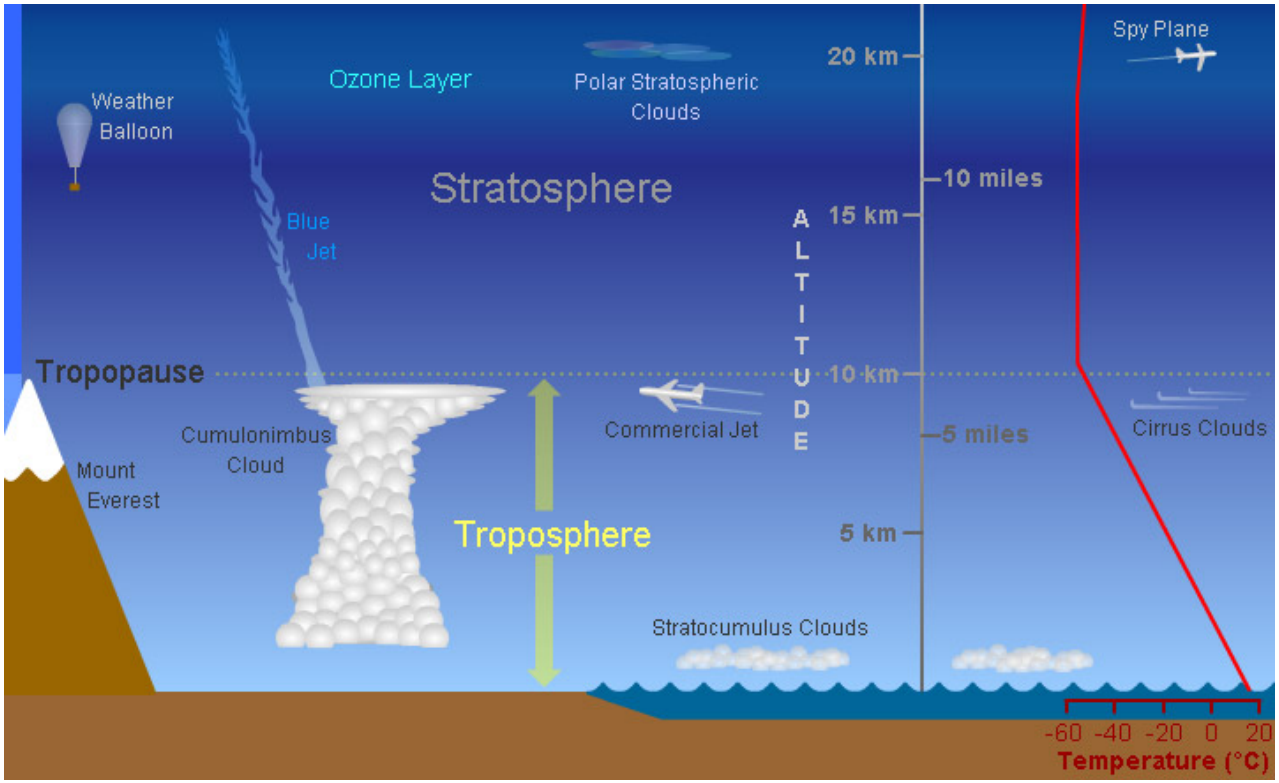
URL: scied.ucar.edu/enso-sorting-game

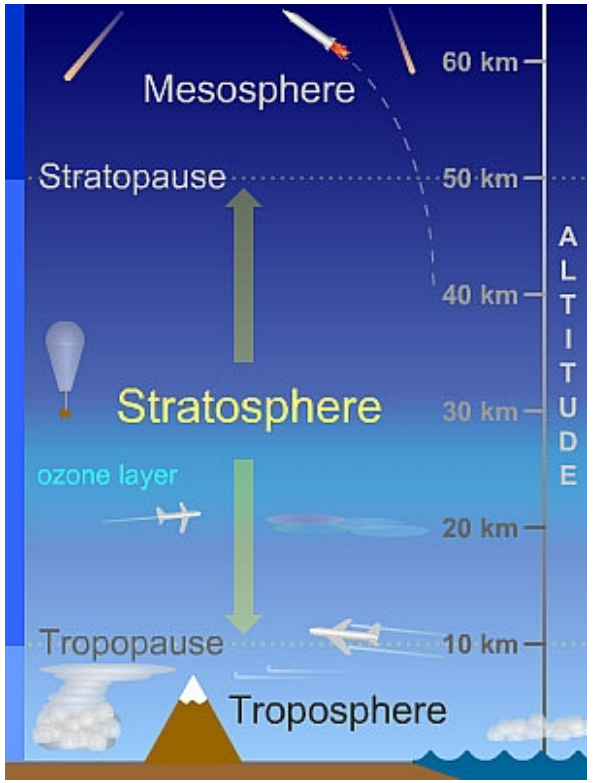
Virtual Ballooning – Atmosphere Layers



URL: scied.ucar.edu/virtual-ballooning

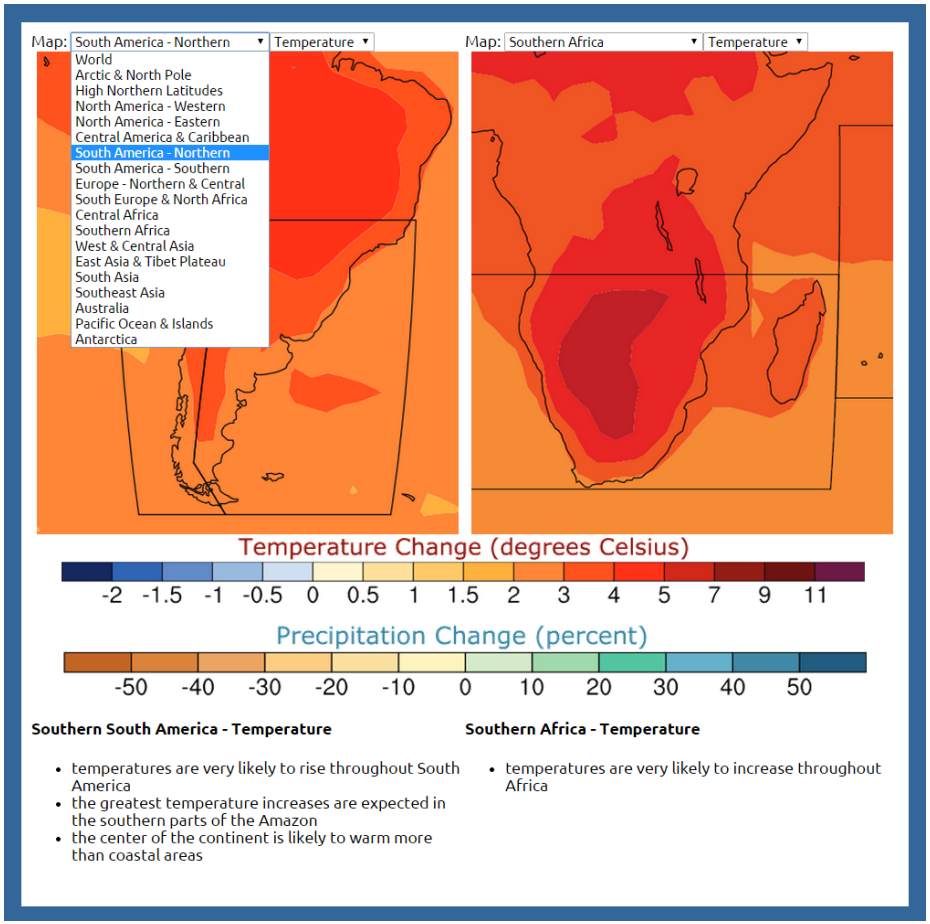
Atmosphere Layers

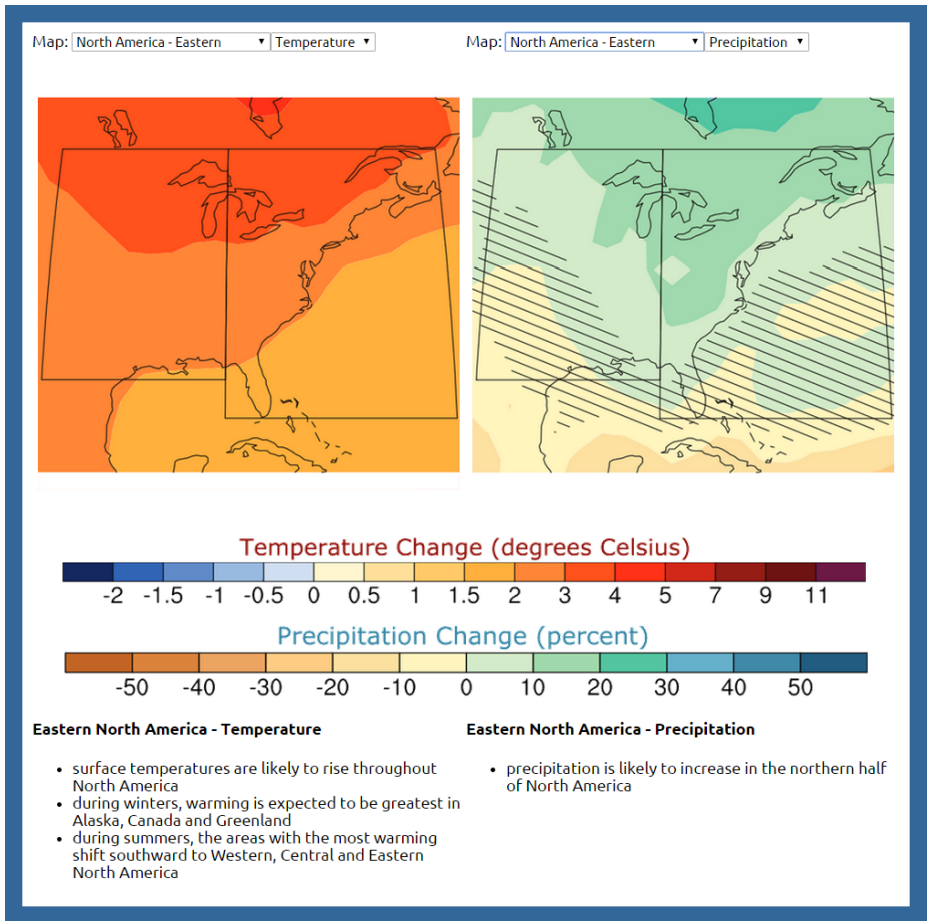




URL: scied.ucar.edu/shortcontent/troposphere-overview
URL: scied.ucar.edu/shortcontent/stratosphere-overview

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