Greenhouse Model
(**http://ccl.northwestern.edu/netlogo/models/ClimateChange**)

This model is based on an earlier version created in 2005 by Robert Tinker for the Enhanced Learning in Science project.
Citation: Tinker, R. and Wilensky, U. (2007). NetLogo Climate Change model.
http://ccl.northwestern.edu/netlogo/models/ClimateChange. Center for Connected Learning and Computer-Based Modeling, Northwestern University, Evanston, IL.

Model startup: sun-brightness = 1.0; albedo = 0.6; no clouds; CO_2 = 0; no clouds)
CO$_2$ is added in increments of 25 molecules; this approximates a change of 250 ppm.

This model is an energy balance model; it is *not* a climate model. In reality, the temperature of a given location is controlled by many things, so the temperature in this model may not reflect actual conditions on the earth (think of air masses, frontal systems, proximity to oceans, etc.). However, this model does allow us to examine the impacts of albedo, CO_2, and clouds on the energy balance of the earth.

Legend
- The Earth is pink; the Earth's surface is green; the atmosphere is blue; and outer space is black.
- Yellow arrows represent incoming solar radiation (shortwave).
- Pine arrows represent heat energy (Infrared radiation, IR) emitted by the earth.
- Red dots represent heat energy that has been absorbed by the earth.

Exercise 1: Modeling the Energy Balance
1. To operate, press **setup** and then **go**. Pressing **go** again will pause the model. You can slow the model down by moving the slider above the model image to the left. For this exercise, do not change anything else (i.e., the amount of CO_2, the number of clouds, the amount of incoming solar radiation [sunlight] or the albedo [reflectivity of the earth]).
2. Press **go**. What happens to the solar energy? You can press **watch a ray** to help you see what is happening. If a ray gets "trapped", just select **watch a ray** again until you get a ray that disappears; you cannot turn off the ray, only select a different one.
3. When do you see IR energy emitted from the earth? Stop the model (Press **go**.) after you see the first IR arrow. Look at the earth's temperature. What does the graph look like?
4. Press **go** to start again. As IR is emitted from the earth, what happens to the temperature?

Exercise 2: Modeling the Greenhouse Gases
1. Press **setup**. Add 25 molecules of CO_2 (approximately equivalent to 250 ppm) by pressing **add CO2** one time.
   a. How do you think CO_2 affects solar radiation?
   b. How do you think CO_2 will affect temperature?
2. Press **go**.
3. What happens when sunlight runs into CO_2?
4. What happens when IR runs into CO_2? You need to wait until the earth is warm enough to emit IR.
5. Was your initial guess correct?

Exercise 3: Modeling the Albedo
1. Press **setup**, and move the albedo slider bar all the way to the right (albedo = 1.00).
   a. What do you think will happen to the incoming solar radiation? Why?
   b. To temperature? Why?
   c. What impact does CO_2 have under these conditions?
2. Press **go** to test your hypothesis.
3. What do you think will happen if we change the albedo to zero? Test your hypothesis.