

Bathtub Model

Last Updated: September 22, 2013

Background

The Earth's atmosphere is like a bathtub. There is a faucet (manmade and natural processes) putting water (greenhouse gases) into the bathtub (the atmosphere). There is also a drain (natural processes) removing the water. Currently, mankind's activities are putting more water in the bathtub than the drain can handle, thus filling the bathtub.

We have already seen the effects of increased water in the bathtub - there is clear evidence that the sky-rocketing levels of greenhouse gases in the atmosphere do harm. Over the last century, man-made climate change has warmed our planet 1-2°C. This seemingly small temperature increase has already contributed to worldwide problems including more severe storms, sea level rise, droughts, increased heat-related deaths, and changes in the growing season. Scientists expect another 4-8°C by the end of the century, leading to changes including severe natural hazards, widespread crop failure, drinking water shortages, significant changes in ecosystem regimes and related industries, and new health problems. If the water spills over the bathtub's edge - the Earth will be so hot that the natural balance between the atmospheric conditions and today's forms of life would be destroyed. In that case, there will be radical changes to life as we know it. It is impossible to know what such a world would look like.

The relation between greenhouse gas emissions (water entering the bathtub), greenhouse gas concentrations (water in the bathtub), and sequestered greenhouse gases (water leaving via the drain, a.k.a. sinks) is very complicated. How long the current natural sink will be maintained is a matter of speculation; this depends on a highly complicated set of variables. Generally speaking, if we stabilize emissions at current levels, the greenhouse gas concentrations will continue to increase within our lifetime because the current sink capacity is smaller than our emissions. Eventually, long after we are all dead, the Earth will reach a new equilibrium where capacity of sources and sinks will be equal. It is unknown if under that equilibrium, Earth will still be inhabitable.

A similar analogy also works for the Earth's energy balance as described in the handout.

Objectives

Students will be able to:

- Describe the bathtub model and how it relates to (traditionally) greenhouse gas concentrations and (additionally) energy.
- Based on the bathtub model, construct a chart of flows (mass of greenhouse gases entering the atmosphere) and stocks (concentration of greenhouse gases in the atmosphere)

Materials Needed

- Bathtub worksheet (with and without answers)

Safety Concerns

None.

Vocabulary

- Greenhouse effect: Thermal radiation (heat) from the planet is absorbed by atmospheric greenhouse gases, and is re-radiated in all directions.
- Greenhouse gas (GHG): A gas in an atmosphere that absorbs and emits radiation within the thermal infrared range (heat). The primary greenhouse gases in the Earth's atmosphere are water vapor, carbon dioxide, methane, nitrous oxide, and ozone.
- Keeling curve: A graph which plots the ongoing change in concentration of carbon dioxide in Earth's atmosphere since 1958. It is based on continuous measurements taken at the Mauna Loa Observatory in Hawaii begun under the supervision of Charles David Keeling.

Procedure

Time	Activity	Description	Supplies
45 minutes	Group discussion	Discuss Pages 1-2 of Worksheet “Bathtub handout (answers).docx”. If useful, refer to additional worksheets provided.	“Bathtub handout (answers).docx”, “Carbon Bathtub Infographic.docx”, “Formulas for Bathtub.docx”
30 minutes	Individual Exercise	Have students break into groups and fill out Page 3 of “Bathtub handout (answers).docx”	“Bathtub handout (answers).docx”

Additional Resources**Reputable Source:**

Climate.gov | NOAA. URL [accessed Aug. 25, 2013]: <http://www.noaa.gov/climate.html>

Fifth Assessment Report (AR5) | Intergovernmental Panel on Climate Change (IPCC). URL [accessed Aug. 25, 2013]: <http://www.ipcc.ch/>

MIT’s Greenhouse Gas Simulator | NOAA Climate.gov. URL [accessed Aug. 25, 2013]: <http://www.climate.gov/teaching/resources/mits-greenhouse-gas-simulator>

National Climate Assessment | US Global Change Research Program. URL [accessed Aug. 25, 2013]: <http://www.globalchange.gov/what-we-do/assessment>

National Geographic (2009): *The Big Idea: The Carbon Bathtub*. URL [accessed Aug. 7th, 2013]: <http://ngm.nationalgeographic.com/big-idea/05/carbon-bath>

Opinion / Newspaper

The Greenhouse Effect and the Bathtub Effect | Dot Earth. URL [accessed Aug. 25, 2013]: http://dotearth.blogs.nytimes.com/2009/01/28/the-greenhouse-effect-and-the-bathtub-effect/?_r=0

The Forum on Religion and Ecology at Yale | Yale. URL [accessed Aug. 25, 2013]: <http://fore.research.yale.edu/climate-change/science/the-greenhouse-effect-and-the-bathtub-effect/>

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Lesson idea from Cliff Davidson, Frauke Hoss, Paul Welle, and Kelly Klima; final product compiled by Kelly Klima on behalf of the Leonard Gelfand Center for Service Learning and Outreach.

Funding Sources

Portions of this work were supported by a) the Leonard Gelfand Center for Service Learning and Outreach, and b) the Center for Climate and Energy Decision Making (SES-0949710) through a cooperative agreement between the National Science Foundation and Carnegie Mellon University.

Next Generation Science Standards Alignment

HS-LS2-7: Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.

Crosscutting Concept: Stability and Change

Connections to other DCIs: HS.ESS2.D, HS.ESS2.E, HS.ESS3.A, HS.ESS3.C