Climate Bathtub Sim Coach Notes and FAQs

Drew Jones
Climate Interactive

With overall team: Tom Fiddaman, Michael Tempel, Linda Booth Sweeney, Peter Senge, John Sterman, Juan F. Martin, Susan Sweitzer, Idit Caperton, Susan Randel

19 July 2007

Important Learning Practices

- Always elicit learner's thinking and estimates before running the model.
- Ask questions to gauge what the learner understands and does not
- Let the learner click the buttons

Overall Flow

Engagement Flow

1. Explain basics of carbon cycle
2. Explain what parts of bathtub and graphs mean
3. Explore past behavior and what has been driving it
4. Offer the goal and explore "Allow increased emissions" future – Learner estimate and model run
5. Explore "Level off" future – Learner estimate and model run
6. Explore "Reduce emissions" future – model run
7. Revisit learnings

1. Explain basics of carbon cycle

Explain briefly how the carbon cycle works. The key points are:

1. There are human-based emissions from two sources – burning fossil fuels and from deforestation. We'll call them "emissions."
2. There are also removals into oceans, plants, and soils.
3. Emissions are much larger than removals.

4. The excess between the two accumulates in the atmosphere.

2. Explain what parts of bathtub and graphs mean

Hit the Play button and pause around 1970 or so.

First orient learners to what they are seeing. Connect the understanding of the carbon cycle to the bathtub analogy. Key points: Inflow is emissions. Outflow is removals. Water in tub is CO2 in atmosphere.

Point to the meters on the tub and explain what they represent.

Point to the graphs on the left and show how the lines correspond to the different parts of the bathtub.

3. Explore past behavior and what has been driving it

You should be paused around 1970 or so.

Point to the graph for CO2 in the atm on the left and ask, "What is the level of CO2 in the atmosphere going up?"

Typical answer is "Because we are emitting more CO2".

Acknowledge this is true but only part of the story. The level of the bathtub is rising because **more is going in than is coming out**. This is a very important point to make early on. Point to the bathtub and the numbers on it to show what is going on.

Here's BIG POINT #1: CO2 in the atmosphere is rising because more is going in than is coming out. Emissions exceed removals.

Hit the Play button again and watch it play up to 2007. Reinforce the point – water in the bathtub is rising because more is going in than is coming out.

4. Offer the goal and explore "Allow increased emissions" future – Learner estimate and model run

Point to the three buttons for future scenarios and explain them. Give them the challenge of choosing a future that will keep CO2 in the atmosphere below 450 ppm (not overflow the bathtub) with minimal difficulty.

Ask what will happen if we continue to increase emissions.

Don’t emphasize this question – it is obvious that the tub will overflow.

Run the scenario. Point out the year (~2038) that the tub overflows. You may want to pause the sim around that time. Watch the overflow.

In the real world, overflowing means passing the goal of 450 ppm. Many scientists believe that passing 450 ppm concentration would mean a triggering of a set of feedback processes that would lead to rapid and severe climate change.

Potential discussion question: What does overflow look like on the ground?

Debrief what happened. Emissions remained above removals so CO2 in the atmosphere continued to grow.

Do this run quickly – move on to the next few.

5. Explore “Level off” future – Learner estimate and model run

Say that now we will test a future where we level off emissions over the coming decades. No more growth.

Ask, “If you were to go to Times Square in New York City and ask 100 people what would happen to CO2 in the atmosphere under this scenario, what would 80 of them say?”

Typical response: “They would say that CO2 in the atmosphere would level off as well. Or actually go down.”

Support this idea with the fact that a study at MIT of technically educated graduate students found similar results. 75% of them had a similar estimate.

Next ask them what THEY think would happen.

Run the Sim. Watch. Note that the overflow happens in 2046 so the effort has delayed the problem for 8 years relative to the first run. This is quite good.

Ask why leveling emissions is insufficient.

Answer: Because we did not reduce emissions down to the level of the removals. We didn't reduce the inflow to equal the outflow, which is the only way to stop the bathtub from increasing.

This is BIG POINT #2: To stabilize CO_2 in the atmosphere, emissions will need to equal removals.

6. Explore "Reduce emissions" future – model run

Explain what will happen in this run. Don't emphasize the learner estimate this time.

Run the future and watch emissions fall to meet removals.

Make BIG POINT #3: To stabilize CO_2 in the atmosphere by getting emissions to equal removals, it will be necessary to make significant reductions (over 50%) in emissions.

7. Revisit learnings

You may want to recap the BIG POINTS.

1. CO_2 in the atmosphere is rising because more is going in than is coming out. Emissions exceed removals.
2. To stabilize CO_2 in the atmosphere, emissions will need to equal removals.
3. To stabilize CO_2 in the atmosphere by getting emissions to equal removals, it will be necessary to make significant reductions (over 50%) in emissions.

Discussion topics:

- If most people think that leveling emissions will level CO_2 in the atm but this is not the case, what would this lead to? (apathy about reducing emissions and subsequent exacerbation of the problem)
- What does a significant reduction of emissions look like in the real world?

Frequently Asked Questions

(Note –Michael Tempel and Susan Randel of Schlumberger/SEED contributed significant sections of the FAQs)

Who made this Sim?

This simulation was conceptualized and built through a collaboration between Schlumberger/SEED, The Sustainability Institute, the Society for Organizational Learning, the System Dynamics Group at MIT, and the MaMaMedia Consulting Group. The numbers that drive the graphs and the bathtub animation were calculated in a system dynamics model built by Dr. Thomas Fiddaman. Schlumberger Ltd. holds the copyright.

Why 450 ppm as a goal?

Already there is much more CO2 in the atmosphere than at any time in the past 425,000 years. In 2007 the concentration of CO2 in the atmosphere was approximately 380 parts per million (ppm). Every year human activities add to that. Some scientists and economists in the climate science world such as David Stern and James Hansen (note) have identified a concentration of 450 ppm as a maximum goal for CO2 that may avoid the most significant damage to the Earth's ecosystems and economies. There is a great deal of uncertainty about the severity of the effects associated with this or any other target level for CO2. We have chosen to use it for this simulation, but we could have set it higher or lower. As you play with the simulation consider how the three scenarios would play out if the bathtub overflowed at a level other than 450 ppm.

How is CO2 in the atmosphere like a bathtub?

The principle at work here is stock and flow. A "stock" is something that accumulates, in this case CO2 in the atmosphere, represented by the water. The bathtub stands in for the Earth's atmosphere. Water (CO2) enters the bathtub (atmosphere) from the spigot above and leaves the bathtub through the drain below. This is the "flow," a representation of how much goes in and how much goes out.

For the past 425,000 years the amount of CO2 in the atmosphere has fluctuated between 175 ppm and 300 ppm. The inflow (the amount of CO2 going into the atmosphere) and outflow (the amount of CO2 removed from the atmosphere) were sufficiently in balance during this period of time to keep the CO2 level within that range. In the past few decades the inflow has increased dramatically. The flows are now out of balance. More and more CO2 is entering the atmosphere, but not nearly as much is being removed. Thus, CO2 increasingly accumulates in the atmosphere. The amount now stands at a concentration of 380 ppm. In our simulation, the bathtub can overflow if the amount of CO2 in the atmosphere increases to the point of significantly altering the climate.

What are the three future options we have in the Sim?

- **Allow Increasing CO2 Emissions**

  One scenario is to allow human emissions of CO2 to increase at roughly current levels. This means that governments around the world would not regulate CO2 emissions, and businesses and individuals would not take any special action to reduce CO_2 emissions. Everything would continue on as it has been going. This "business as usual" or "status quo" approach asks: What if we did nothing?

The numbers used in this scenario were the "business as usual" estimates of the Intergovernmental Panel on Climate Change (IPCC), the international group dedicated to studying this issue. In this scenario, removals increase naturally, but are never able to keep up with the increase. By the year 2045 the levels would reach 450 ppm. This amount would cause significant changes in the atmosphere, and global warming would cause dramatic changes to the environment.

In our climate simulation, the bathtub would overflow by 2045, and we would experience even more significant climate change. This future is what the IPCC scientists expect will happen if we make no major changes to avert climate change.

• **Level Off CO2 Emissions**

Another option is to gradually stop the increase of human-caused emissions of CO_2 in the decades following 2007. This scenario is based loosely on the Kyoto Protocol, an international treaty to reduce CO_2 emissions. The treaty was negotiated by the United Nations Framework Convention on Climate Change (UNFCCC) in 1997 and went into effect in 2005. More than 150 nations were involved in creating the Kyoto Protocol, and 84 countries signed the agreement. However, the agreement also needed to be ratified by each country, and not all who signed the protocol ratified or approved it at home. The leading industrialized countries that have include Russia, Japan, and the members of the European Union. Other countries have since joined the agreement, bringing the total to more than 165. The United States and Australia are among the industrialized countries that signed but did not ratify the Kyoto Protocol.

The countries that did agree to follow the protocol produce about 60% of the world's greenhouse gases. The agreement is for industrialized countries to reduce greenhouse gas emissions to 5.2% lower than 1990 levels by 2012. This would roughly level off CO_2 emissions. But is stabilizing emissions enough to prevent CO_2 levels from going above 450 ppm?

• Reduce CO2 Emissions

What if all the governments in the world agreed to significantly reduce CO_2 emissions? A plan like this has been proposed by former U.S. vice president Al Gore. Climatologist David Stern has proposed something similar. This scenario calls for reducing emissions of CO_2 by 58% of the 2007 level by 2070. What would happen to our bathtub? Would it still overflow?

Questions about CO2 and Climate Change

What are CO2 emissions?

Carbon dioxide (CO_2) is a gas that makes up a tiny fraction of the Earth's atmosphere. It occurs naturally, mostly as a result of breathing, of decay, from the burning of wood and the release of CO_2 from the oceans. CO_2 emissions also result from the burning of fossil fuels and other human activities. It is this human-generated CO_2 that we are showing in our simulation.

What are CO_2 removals?

Carbon sinks remove carbon from the atmosphere. The main carbon sinks responsible for removals are photosynthesis and absorption by the oceans.

The oceans are both a carbon sink and a source of CO_2. There is an ongoing exchange of CO_2 between the atmosphere and the oceans. The balance depends upon factors including water temperature and the concentrations of CO_2 in both the oceans and the atmosphere.

For hundreds of thousands of years emissions and removals remained roughly in balance with the concentration of CO_2 in the atmosphere varying between 180 and 300 parts per million (ppm). This was true until humans began to burn fossil fuels during the Industrial Revolution. These additional CO_2 emissions are the problem. Currently much more CO_2 is being released than can be taken up by plants or absorbed by the ocean. The concentration of CO_2 in the atmosphere is now 380 ppm and rising.

Why do removals seem to follow emissions?

Carbon dioxide flows between the atmosphere, biosphere, and oceans in order to maintain a balanced distribution. When the concentration of CO_2 in the atmosphere increases, two things happen:

- "CO_2 fertilization" occurs. Plants use more CO_2 for photosynthesis, growing more leaves and woody material.
- The surface ocean—mixed by wind-driven waves— quickly absorbs CO_2, which then diffuses more gradually into the deep ocean.

Both processes have limits. The oceans can only absorb so much CO_2 before releasing as much CO_2 back to the atmosphere as was taken up. For plants, the limitations on growth from water and other nutrients become important. This is called "sink saturation."

In the "Allow Increased Emissions" future, removals increase because the rapidly-growing concentration of CO_2 in the atmosphere continues to drive uptake. Part of the excess CO_2 is absorbed by plants and the oceans.

In the "Reduce CO_2 Emissions" future, removals fall because the excess of CO_2 in the atmosphere above that in the biosphere and oceans is not so great.

What's the connection between CO_2 and climate change?

We know that CO_2 absorbs heat from the Sun and releases it into the atmosphere. Going back millions of years, when the concentration of CO_2 was higher, the Earth was warmer. Eventually CO_2 concentration dropped and the world became cooler. Since the 1740s CO_2 concentration has increased significantly, and the average temperature on Earth has also increased.

Why does the CO_2 level in the atmosphere continue to rise even when emissions are leveled off?

This scenario corresponds to clicking the middle button in our simulation: "LEVEL OFF CO_2 EMISSIONS." After about 2045 emissions are no longer increasing. At that point removals are also level from year to year. But since emissions are greater than removals, each year more CO_2 goes into the atmosphere than is removed. So the amount of CO_2 in the atmosphere continues to rise.

It's like a bus traveling through the city with people getting on and off. Let's say that at one stop 5 people get on the bus and 3 get off. At the next stop the same thing happens: 5 people get on and 3 get off. If this pattern continues the bus will get very crowded. The number of people getting on the bus is level: 5 at each stop. But since only three people get off there is an increase of 2 people each time the bus stops. In order to keep the crowding from getting worse, the same number of people have to get off the bus as get on. And to reduce the crowding, more people have to get off than get on.

In order to keep the concentration of CO2 in the atmosphere at a given level, say 450 ppm, emissions and removals have to be equal. In order to reduce the concentration of CO2 in the atmosphere, removals have to be greater than emissions.

Where can I learn more?

The Sim is on the web at:

http://climateinteractive.org/simulations/bathtub/the-climate-bathtub-animation

The contact at Climate Interactive is:

Drew Jones 828-236-0884

apjones@climateinteractive.org

http://climateinteractive.org/

Presentation Script

Ideally, the Sim is presented in an interactive approach, as described in this document. The presenter should ask questions of the learners and engage them in thinking together. However, if one is simply presenting the findings, then the script below might be a helpful approach.

(starting the sim paused in 1968 or so)

To sustain life on Earth, we are going to need to stabilize heat-trapping carbon dioxide levels in the atmosphere.

I'm here to talk about why, for us to stabilize these levels, we need to REDUCE in global carbon dioxide emissions – not just end their growth. Emissions need to come down, not just level off.

CO2 accumulates in the atmosphere like a bathtub.

- It fills with emissions – burning fossil fuels and deforestation. That's the purple water.
- It drains from removals – CO2 naturally getting dissolved into oceans and collecting in trees and plants and soils. That's the orange water flowing out.

In 1968 about 5 gigatons of CO2 per year was going in and about 3 GT per year was coming out, so what was happening?

[click arrowed play button]

Well, more was going in than is coming out…

Yeah, CO_2 has been accumulating to the point where in 2007 there is about 380 ppm. Right here in my hand.

And today there is about 10 gigatons per year going in and 5 going out.

That's because inflows and outflows have been increasing for a long time. Since 1950, emissions have been going up – see the purple line, removals too – that's the orange line. And CO_2 has been accumulating from 320 ppm to 380 ppm.

So here's our challenge. How to keep CO_2 in the atm – the level of water in the bathtub -- below the goal of 450 ppm – the red line on this graph? Nothing magic happens at that level – there is no real "top" to the bathtub. It could keep going up and up. 450 is a good goal.

Well, WHAT IF we allow increased CO_2 emissions?

[click "allow increased…." Button]

Of course, we blow past the 450 ppm goal. But think, what if we level off our emissions? What if grow a few years and then CAP them? No more growth? What if the purple line curved over? If the inflow stopped under 11?

Researchers at MIT did a study on this question – most people think we would solve the problem – CO_2 levels would stabilize or even drop. The blue line would flatten. The tub would not overflow. Makes sense, right? Cap emissions and at least we wouldn't be making things worse, right?

[click "level off…" button]

Wrong!!

More is still going into the bathtub than is going out!!! Emissions are still bigger than removals!! The purple line is still above the orange line! More is still going into the bathtub than is going out!!!

Now this would HELP. CO_2 accumulates more SLOWLY – the blue line is a tiny bit flatter -- things are getting worse at a slower rate. We reach 450 ppm 8 years later and delay the problem. But we haven't addressed it fully.

So… [click "reduce emission…" button]

To stabilize levels of CO_2 in the atm, We need to reduce emissions down to the point where emissions from fossil fuels and deforestation equal removals into oceans and plants. Where the inflow equals the outflow, the level of water in the bathtub is flat.

Because removals drop with levels of CO_2 in the atm – see the orange line dropping down-- that's going to take about an 80% reduction in fossil fuel emissions by 2050. 80% reduction by 2050.

THAT's why we need big REDUCTIONS in CO_2 emissions, and why leveling off or capping emissions DELAYS the problem won't be enough to solve it.

80% by 2050.

Resources

To understand the public understanding of climate dynamics, read the paper by John Sterman and Linda Booth Sweeney. It also explains climate dynamics with a bathtub perspective quite clearly.
http://jsterman.scripts.mit.edu/docs/Sterman-2007-UnderstandingPublicComplacency.pdf