Ice Under Fire

A Live Science Demonstration about Polar Science & Global Warming

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2007

A twenty-minute demonstration for children and adults

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Introduction

Demonstration Description

A twenty minute live science demonstration requiring one demonstrator.

The demonstrator will lead the audience through an exploration of how ice contributes to knowledge of global warming. The demonstration will use research from polar science to examine global warming, ending by empowering people to make changes in their life choices to combat global warming.

Promotional Copy

What mysterious powers does ice possess that may impact the fate of the ocean and the world? Use the analytical tools of polar science to examine global warming. Audience members will observe various kinds of ice, make predictions about on-stage experiments, and learn how scientists use ice as a “time machine” to travel back in time and observe Earth’s atmosphere 650,000 years ago. Just as important as its blazing effects and experiments, the demonstration ends with an empowering presentation of some solutions that can be done by grown-ups and kids alike.

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Learning Objectives and Concepts

Learning Objectives

After watching this demonstration audience members will be able to:

- Describe one way in which ice is important in understanding global warming;
- Describe one difference between carbon dioxide and non-greenhouse gases;
- Increase in motivation to make life choices that contribute to solving global warming.

Concepts

- We can learn about global warming from polar ice; global warming affects polar ice.
- As a greenhouse gas, carbon dioxide reacts differently to the Sun's radiation than oxygen or nitrogen, and this causes a positive feedback loop as the Sun warms the Earth and the greenhouse gases trap the heat next to the Earth.
- Scientific knowledge combined with societal will can lead to changes in the environment – for good as well as ill.

Outline of Demonstration

Announcement

"Ladies and gentlemen, beginning in fifteen minutes on the Demonstration Stage will be Ice Under Fire, the coolest hot new demonstration at the Science Center. This demonstration is all about polar science and global warming. You don't want to miss this one, so hurry over to the building one demonstration stage and grab a seat."

(Show outline on the following page.)

Summary/Conclusion

Using the tools of science and all working together, we can solve this problem. But a perfect solution isn't just going to drop from the sky. Some of these solutions are easy to do, and some of them are hard. Some are more helpful than others, but the more you do the faster we can solve this.

Thank you very much for joining me. This show was developed by the Pacific Science Center in conjunction with the Polar Science Center at the University of Washington. Here are lists of solutions you can be part of and places to find more information. Pick one thing YOU can do and start there! Have a wonderful rest of the day here at the Science Center!

Title of Each Activity, Key Concepts, and Transition

Activity	Key Concepts	Transition to next section
Introduction		
Introduce yourself & theme of demonstration.	Welcome!	
Set up earth model showing ocean rise.	Ice, water, and land are all part of the earth	You already know about ice.
Ice: Polar scientists examine ice bubbles.		
Make ice with liquid nitrogen.		This is too cold to touch, let's look at regular ice first.
Observe "regular" ice.	Ice has bubbles full of air.	Let's look at different ice.
Observe ice made with LN2.	The air in the bubbles is from the time the ice was frozen. Bubbles in ice are time capsules.	That ice was very white.
Demonstrate the concept of albedo/reflection.	White reflects better. Our poles reflect sunlight.	Bonnie, a polar scientist studies reflection.
Show a model ice core.	Ice can be really old.	Other polar scientists study what's inside the bubbles.
Fire: Polar scientists examine the air trapped in ice bubbles.		
Establish content of earth's atmosphere.	CO_2 exists.	
Extinguish a flame with CO_2.	CO_2 behaves differently from O_2.	Here's why scientists are interested in CO_2.
Show models of molecules responding to heat.	CO_2 does the greenhouse gas jiggle – it traps heat.	If there's CO_2 in the atmosphere ...
Demonstrate CO_2 build-up with Sun-Earth feltboard.	Global warming is a positive feedback loop	What has happened to our earth model throughout the demonstration?
Torch ice in earth model of ocean-rise.	With Global warming oceans rise.	Humans have made this problem. And humans can solve it. But a solution won't drop from the sky.
Conclusion		
Reveal solutions & demonstrate how each action improves the situation.	Using the tools of science and working together, we can solve this problem.	Thank you!
Thanks!	Music	

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Ice Under Fire - Script

This is what you do. (And often some advice.)
P: This is what you say.
V: This is what the audience says.

INTRODUCTION

P: *Play ice-themed music.*

P: Welcome to the Ice Under Fire! My name is Alice and I'm going to be the demonstrator for this show. *Ice under Fire* is going to be about ice and fire, about polar science and global warming. How many of you have heard about global warming?

V: Me!

P: Yes, a lot of people are talking about it now. As scientists try to understand global warming, many of them are looking at ice. That's what we're going to do today: Look at ice, asking two questions: One: What do scientists find out from ice that helps them understand global warming and two: Why do we care? I mean, we live in Seattle. Who wouldn't want a few more sunny warm days?

EARTH MODEL SHOWING OCEAN RISE

P: Let's start our first experiment. This is a model of the earth. The water in the graduated cylinder is representing the ocean, and the ice in the cone is representing the ice in Antarctica. It's in a mesh cone because the ice in Antarctica is on land, not floating in the ocean like the ice at the North Pole.

P: First we'll mark the level of the water in the ocean. What would you see if you went to the edge of the ocean?

V: Seashells!

P: This is where the seashells and beach-houses are, just on this line. Also, Seattle's waterfront and the aquarium are right here.

P: As time passes, what is going to happen to the ice?

V: It'll melt!

P: You betcha. So shall we just sit here and watch this melt?

V: Umm, no...

P: We'll let this experiment go throughout the demonstration, and see how the level changes as the ice in "Antarctica" melts.

P: You knew the ice would melt, so you already know a lot about ice. What is ice?

V: Water!

MAKE ICE WITH LIQUID NITROGEN

P: How do you make ice?

V: You freezer it!

P: Great, and it usually takes several hours to freeze. You usually have to wait overnight for your ice to freeze. I'm going to make ice here, right before your very eyes, in just 30 seconds. Want to see that?

V: Yeah!

P: Here I have some room-temperature water in an ice-cube tray. I'll put that in this cooler here. Now, to make this ice I'm going to use liquid nitrogen *(show dewar)*. Liquid nitrogen is -319^{o} F *(put up sign).* Is that cold enough to freeze water?

V: Yes!

P: Is that cold enough to freeze me?

V: Yes!

P: Yup, in fact it's so cold that it's a bit dangerous, so I'm going to wear my goggles, lab coat, and safety gloves as I pour some LN_2 into the cooler. *Pour LN_2 into the cooler.*

P: We still have to wait about 30 seconds or a minute while this water freezes. *Hold ice cube tray down in the LN_2 with tongs, it tends to float away.* While we're waiting I'd like to thank Byrne Specialty Gasses for donating the liquid nitrogen to this demonstration. (Depending on how long it takes to freeze your ice, you can also thank the University of Washington Polar Science Center, and ask visitors for their experiences of how ice varies.)

P: Pull tray out of LN_2 cooler and replace the lid. *Show ice cube tray; tip over to show the water not flowing out. Your ice may not be completely frozen, but as long as you have a good bit of ice, you're okay.*

P: Ta-da! Ice! Does this look frozen to you?

V: Yup!

P: This ice is -319^o F right now, so before we can safely look at it closer we'll have to warm it up a bit. *Put the tray in a pan of room-temperature water.*

OBSERVE "REGULAR" ICE

P: So let us take a look at some other ice first. I need six volunteers.

V: Me! Me! Me!

P: *Pick 6 volunteers: one from each section of the audience.* Come on up here to the blue line of safety. Take one of these cups back to where you were sitting, show it to everyone you were sitting with and then pass it on. *Pass out ice from the café in cups.* Please make sure everyone gets a chance to look at the ice.

P: *Hold up a piece of ice from the café.* What do you see?

V: White strings! It's see-through! Bubbles!

P: Yes! All of those things. Tell me about those white hairs, look closer, what are they made of?

V: Bubbles?

P: There is air inside those bubbles. It's the air from three hours ago when that ice was frozen in the café. Looking at that air is kind of like looking back in time, like a little time machine. The air is just like the air around us now: it has a little oxygen, a lot of nitrogen, some carbon dioxide and a few other things.

OBSERVE ICE MADE WITH LIQUID NITROGEN

P: Now let's look at the ice we made faster, using the LN_2. *I need six more volunteers.*

V: Me! Me! Me!

P: *Pick 6 volunteers: one from each section of the audience.* Come on up here to the blue line of safety. Take one of these cups back to where you were sitting, show it to everyone you were sitting with and then pass it on. *Pass out LN_2-ized ice in cups.* Please make sure everyone gets a chance to look at the ice.

P: *Hold up a piece of the LN_2-ized ice.* What do you see? Is it any different?

V: It's white!

P: What was the white part in the other ice?

V: Bubbles!

P: So it's the same in this ice, only there are way more bubbles. Those bubbles are full of air from five minutes ago when I froze that ice.

P: This is a microscope picture of bubbles in ice. *Put up bubbles image.* There are two important things about the bubbles in ice: first they change the color of the ice and make it whiter and less see-through. Second, they trap air from the time the ice was frozen.

P: So, how long ago did I freeze this ice?

P: 5 minutes!

P: So the air inside this ice is 5 minutes old. If we examined this cloudy ice, and probably find out that there was a lot of nitrogen in the air around it when it was formed, since it was frozen using liquid nitrogen.

P: When you're done looking at the ice, pass it up to the front, and I'll have my friend here (*pick a volunteer*) place it in front of the penguins.

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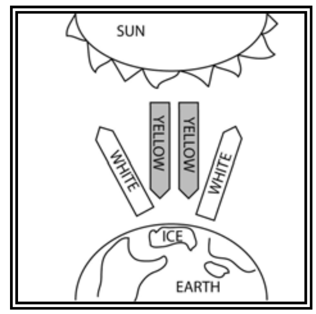
DEMONSTRATE ALBEDO/REFLECTION

P: A friend of mine, Bonnie (*that's really the name of the woman who took the ice core we've modeled*), studies the numbers of bubbles in ice, she's studying how reflective it is. She takes ice cores: she drills into the ice in the Arctic Ocean and pulls up samples of ice from way down deep. *Get out ice core.* This is a model of one of her ice cores that she took 12 months ago.

P: *Get out black/white plates.* So you can see the number of bubbles changes the color of the ice. Here are two colors. *Shine flashlight on plates.* Which color reflects light better, black or white? Which color looks brighter?

V: White!



P: And whiter ice reflects light better too. That's exactly what happens here on Earth. *Put up the Sun, the Earth, the sun's rays, and the light reflected by the ice.* The Sun warms up the Earth; ice reflects some of that heat, keeping the Earth cool and "just right."

ICE CORE

P: So this ice core model is basically a giant ice cube. This ice is old – it's was formed in the summer of 2006 (about 12 months ago). So how old is the air trapped inside the bubbles in this ice core?

V: 12 months!

P: Do you think it might be useful to scientists to time travel and look at the air from different times in the past?

V: Yes.

P: Yeah, in fact, in some ice cores from Antarctica we can look back as far as 650,000 years, and see changes over time. In this case, Bonnie was looking to see how many bubbles there were, and how white and reflective the ice was 10 months ago. The other important thing scientists are studying about polar ice is this: What kind of air is inside those bubbles.

P: Let's do that, and look closer at the air. We already mentioned that the air isn't just oxygen, but nitrogen, carbon dioxide and some other things. Everyone take a deep breath.

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V: *Breathe in.*

EXISTENCE OF CARBON DIOXIDE - EXTINGUISHING FLAME

P: You know there's oxygen in the air, because that's what we need to breathe. Nitrogen is pretty much a filler, but let's take a closer look at the carbon dioxide. Where does carbon dioxide come from?

V: Us! Breathing! Cars!

P: Yes, and volcanic activity, burning coal, burning petroleum, and deforestation all also create carbon dioxide. Everyone look closely at the air, can you see the carbon dioxide? *Cross your eyes, look closely at the air, or at least make a show of it.*

V: Umm… no.

P: That's because it's an invisible gas. We'll have to detect it some other way.

P: *Light candle in beaker.*

P: I know from what I learned here at PSC that fire needs oxygen to burn, so there must be oxygen in the beaker. We'll know if the candle goes out we'll know that there isn't any oxygen in the beaker anymore.

P: I can make carbon dioxide with vinegar and baking soda. *Make carbon dioxide with vinegar and baking soda.* You see the bubbles? Those are full of carbon dioxide, and as they pop, they're filling this beaker up with carbon dioxide.

P: Carbon dioxide is heavier than oxygen, so I can pour it into the beaker, and it will sink to the bottom, forcing the oxygen out. *Pour the CO_2 (not the liquid!)*.

V: Wow!

P: Did I pour any of the liquid in?

V: No.

P: So it must be the carbon dioxide. Well, maybe I did something wrong. Maybe the candle just burned out, so let me try relighting it. Try to light candle with a match. The match will gutter out before you reach the candle.

P: We definitely have carbon dioxide in this beaker, even though you can't see it.

MOLECULE MODELS

P: Let me show you the difference between carbon dioxide and oxygen. Here I have two models (*hold up O_2 and CO_2 models*). This one is a model of one molecule, one piece, of oxygen or nitrogen, they're pretty much the same. This one is a model of one molecule, one piece, or carbon dioxide.

P: Most of our atmosphere is like this, made of oxygen and nitrogen. It floats around, bouncing off stuff, and doesn't do much. *"Float" the molecule around your head.*

P: A neat thing happens when the sun shines on out atmosphere. *Demonstrate this by putting the molecule against the Sun/Earth model like the sun is shining on it.* The sun is so bright that it heats things up. You can feel the sun on your face on a hot summer day. Well, it is actually making the molecules in your face jiggle around, that's how you feel it. *Wiggle your face.* It does the same thing for oxygen. *Wiggle the oxygen.*

P: That's normal. Carbon dioxide acts a little differently. When the reflected IR gets to the carbon dioxide, the carbon dioxide catches it, and won't let it go. You can see this, because the carbon dioxide acts differently. *Wiggle the CO_2.*

P: What's happening?

V: It's flapping!

P: The carbon dioxide molecule can store more of the energy. This wiggling is what makes carbon dioxide a greenhouse gas. This is why carbon dioxide contributes to global warming.

P: (use Ice bubble picture or graph) When scientists looked in the time capsules of polar ice bubbles, they found that the amount of CO2 in Earth's atmosphere has a regular cycle of higher and lower levels. Over 650,000 years of records, the cycle repeats over and over. But right now the level of CO2 in the atmosphere is far, far, far above the historic cyclical levels. The industrial revolution and all of humanities engines are speeding up the effects of global warming.

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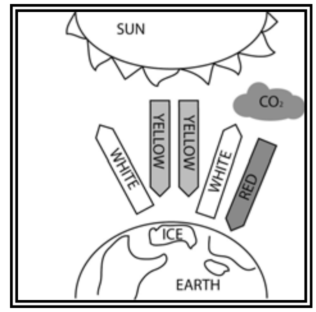
SUN-EARTH FELTBOARD - CO_2 IMPACT



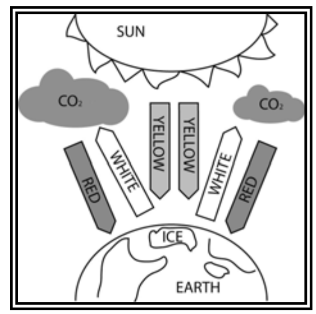
P: *Go back to the Sun/Earth/Arrows.* If there's carbon dioxide in the atmosphere (*put up the small CO_2 cloud over one of the reflection arrows*) it can absorb some of the heat reflected by the ice and trap that heat next to the Earth (*put the re-radiated heat arrow up*).

P: How many arrows are pointed at the Earth?

V: Three!

P: And how many are pointed away?

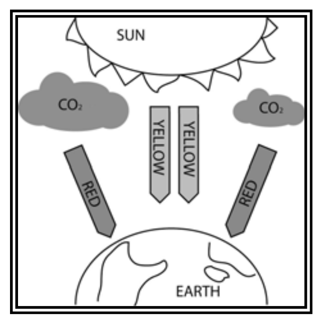
V: Two!



P: As there is more carbon dioxide added to the atmosphere (*bigger CO_2 sign and re-radiated arrow*) the balance between heat and reflected heat is messed up: more heat is trapped and the temperature of the Earth rises. This is global warming.

P: So, what happens to ice as temperature rises?

V: It melts!



P: Yup. *Remove ice sign and put it off to the side.* Oh, and that means we don't get to keep these arrows (remove reflection arrows).

P: So now how many arrows are pointed at the Earth?

V: FOUR!

P: And how many are pointed away?

V: None

P: (Repeat "Four! None!" if you like). Is this balanced?

V: No...

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TORCH ICE IN EARTH MODEL OF OCEAN-RISE

P: Let's look back at the experiment we started at the beginning. The water in the graduated cylinder is representing the ocean, and the ice in the box is representing the ice in Antarctica or Greenland. It's in a mesh box because the ice in Antarctica and Greenland is on land, not floating in the ocean like the ice at the North Pole.

P: What's happened so far?

V: Some of the ice has melted.

P: We haven't really had enough time for all this ice to melt, so I'm going to speed up this experiment a lot. Normally this melting would take months or years, sometimes rising a few feet over few days, sometimes centimeters a year. *Get torch, stall, make it funny.* I think before we do this experiment we should take the Safety Oath. *Lead visitors in a safety oath.*

V: *Take the Pacific Science Center Safety Oath.*

P: *Light torch.* Watch what happens to the level of the ocean as the ice melts.

P: *Finish melting ice. Use appropriate safety precautions.* Now, this change will take decades. Remember I'm speeding up time by using this torch.

P: *Here are comments to add as needed while melting the ice, but bear in mind the torch makes enough noise that they may not hear you:* Global warming is not an idea that only a few scientists have. There is overwhelming agreement. Just in 2007 the United Nations released a report created by 2500 scientists from around the world agreeing that this is the most important problem facing our planet.

P: *More information to add if needed:* Is the water level rising? We're showing you what would happen if one of the large ice shelves in Antarctica or Greenland melted. This is definitely occurring. A few years a go an Antarctic Ice Shelf the size of Rhode Island fell into the ocean. If we lose one of the large shelves, the ocean level would rise 20 feet.

P: Where is the aquarium now?

V: Under water!

P: Remember the original level is where all the beach houses and Seattle's waterfront are. *Show map.* Here's a map of what would happen to Puget

Sound if one of the big ice shelves in Antarctica or Greenland were to melt. The red part is land that would be underwater if that happened. The rising of the ocean is only one of many problems that will occur with global warming. There are others as well – increased storms, change in rainfall patterns, and extinction of plants and animals.

SOLUTIONS & CONCLUSION

P: Human beings have created a difficult situation here. Luckily, there are lots of ways that human beings can solve the problem. Using the tools of science and all working together, we can turn this around. But a perfect solution isn't just going to drop from the sky. *Pull cord to release scrolls listing solutions so they unfold from the ceiling. Or, pull out a box of solution-slips and scatter them around the stage. Start upbeat music.*

P: There are many things that we all can do, but far and away the most important is reducing the amount that every one of us drives. Look what this can do. *Use turkey baster to remove some water from the graduated cylinder. Read several choices of actions and each time remove some water until the water level is back to its original height.*

P: This can be expensive, like buying a car with low emissions. It may be as simple as riding your bike to the store instead of bugging your parents for a ride. But you see, together we can stop this from happening.

Here we're doing our part: ___ of our employees bus or carpool to work (at Pacific Science Center it's 50%)

(other solutions you may mention: Use Alternative Energy: Seattle is supplied by 93.7% electricity that doesn't contribute to global warming

P: We have handouts here that you can take home with you if you're interested. Remember: The more you do the faster we can solve this. Enjoy the rest of your day at Pacific Science Center and BE PART OF THE SOLUTION!

P: Thank you!

P: *Play an energetic empowering piece if music such as Melissa Ethridge's "I Need to Wake Up."*

Guide to Activities

Safety for Demonstrator

Hazardous materials used in this demonstration include: Liquid Nitrogen, propane torch, and matches.

Use all appropriate safety handling procedures for the LN_2: gloves, goggles, and keep it away from visitors.

Do not hand out the ice made with LN_2 until ***it begins to melt in your hand***. Once it begins to melt you know the temperature is $0^{o}C$ – and therefore safe.

Use all appropriate safety procedures with the matches and the candles.

When using the blow torch wear goggles, point only at the ice and approved containers (metal funnel and ring), read the instructions, be trained, turn it fully off when finished, and store it in the combustibles cabinet.

Safety Concerns for Visitors

If you hand out the ice made with LN_2 before you feel it melting in your hand, visitors could get severe cold-burns.

Overall Suggestions for Demonstrator

The reflected sunlight diagram is a greatly simplified concept. In actuality there is more absorption and re-radiation than reflection, but that's a whole concept that would take too much time to explain in this demonstration.

The CO_2/O_2 molecule demonstration is somewhat simplified, but not as much as you might think. In fact, with a little study on your part you can present what is happening and the concept of resonance at a fairly high-level: high-school and college physics classes could learn a lot from it. Also this could be presented to interested, intelligent adults outside of the demonstration.

Say "carbon dioxide" not CO_2.

This demonstration does not "debunk the debunkers" it simply presents some scientific principles that led to the discovery and proof of global warming. Global warming science demonstrators have found that they are not often challenged to defend the existence of global warming, given the self-selecting nature of science museum attendees.

Examine your presentation for "scare tactics." Spend some time stressing the time that this change will take: ocean rise will not be in the form of an instantaneous tidal wave. Explain the gravity of the situation without being overly panicked about it. Make sure your ending is upbeat and empowering. Use of music is helpful.

Activity Description:

Earth Model Showing Ocean Rise

Set up:

Fill a large graduated cylinder with tap water and blue food coloring.
Position graduated cylinder under a ring stand.
Place funnel in the graduated cylinder
Place the wire mesh cone in the ring.
Position ocean/land image behind graduated cylinder.
Place torch to the side.
DURING DEMONSTRATION:
add three handfuls of ice in the mesh cone.
Mark ocean level on graduated cylinder with bright tape.

How to torch the ice:

tape at the top of the ocean.
Torch the ice by pointing the torch flame through the mesh.
Move the torch around so no one area of the mesh becomes red hot.

Safety:

Do not point the torch at anything that hasn't been approved.
Wear goggles.
Follow torch instructions.
Don't melt the laminated image with the torch.

Make Ice with Liquid Nitrogen

Set up:

¼-dewar of LN_2
Large Styrofoam cooler
Fill silicon ice-cube tray holes 2/3 full of water. Do not fill the last row of ice-cube holes to give yourself a handle for the tongs.
Fill a shoe-box sized plastic container 1/3 full of room-temperature to lukewarm water
Gather tongs, gloves, goggles, and LN_2-temperature signs

How to:

Place the ice-cube tray in the bottom of the cooler.
Using appropriate safety precautions pour enough LN_2 into the cooler to float the ice-cube tray.
Pour the LN_2 towards one end of the cooler: attempt not to pour directly on the ice-cube tray, this causes the water to splash out of the holes.
Using tongs, hold ice-cube tray down, but keep moving it around so it doesn't freeze to the bottom of the cooler in any spilled water.
Using tongs, remove the tray from the cooler by pinching the unfilled end of the ice-cube tray.
Place the ice-cube tray right-side-up in the Tupperware of water.

Safety:

Follow your institution's safety protocol for LN_2.

Realize that the ice is the same temperature as LN_2 to begin with, don't touch it until it is melting, or begins to melt immediately when you touch it.

Clean up:

Dispose of LN_2 left in cooler appropriately.

Observe "Regular" Ice

Set up:

Have six cups set out.

During the demonstration put 2-3 ice cubes from the café in each cup.

How to:

Call up six volunteers to the stage.

Give each volunteer instructions to make sure everyone in the audience sees the ice.

Ask for audience observations of ice.

When done ask that all cups be placed at the end of the front row, or on the stage (pick one location).

Safety:

Plastic cups can break and make semi-sharp pieces.

Observe Ice Made With Liquid Nitrogen

Set up:

Have six cups set out.

When the LN_2-ized ice is warm enough to melt, place one cube in each cup.

How to:

Call up six volunteers to the rope.

Give each volunteer instructions to make sure everyone in the audience sees the ice.

Ask for audience observations of ice.

When done ask that all cups be placed at the end of the front row, or on the stage (pick one location).

Safety:

Plastic cups can break and make semi-sharp pieces.

LN_2-ized ice that doesn't melt in your hand is TOO COLD and can cold-burn visitors.

Demonstrate Albedo/Reflection

Set up:

Sheet of paper or a sign that is half black & half white.

working flashlight

How to:

Hold up black/white sintra.
Point the flashlight at the middle so it shines on both colors.

Safety:

I recommend against shining the light directly into your eye for an extended period of time.

Clean up:

If storing for more than two weeks remove the batteries from the flashlight.

Ice Core

Set up:

Have the ice core.

How to:

Hold up the ice core.

Safety:

Don't whack people with the ice core.

Existence of Carbon Dioxide – Extinguishing Flame

Set up:

Put 2 tablespoons of baking soda in a large flask.
Prepare a small graduated cylinder with 60 mL of vinegar and one drop of red food coloring (let sit, it will mix itself).
Put votive candles in a beaker with a wide mouth (about 10 cm).
Set out a box of matches.
Set out combustion tongs.
Have goggles.

How to:

Light the two candles (use tongs and a match)
Pour the red vinegar into the baking soda flask.
Wait for the reaction to calm down.
Pour the resulting carbon dioxide (gas in the flask) into the beaker, slowly and carefully. Do not pour the liquid. The candles will go out.
Attempt to relight the candles: your match will gutter before reaching the candles.

Safety:

Exercise appropriate caution with matches and candles.
Don't drop glassware.

Molecule Models

Set up:

Large models of O_2 and CO_2 molecules
Have the Sun and Earth feltboard up already.

How to:

Demonstrate energy transfer and jiggling according to script using props and your body.

Safety:

Don't throw the molecules at the audience.

Sun-Earth Feltboard – CO_2 Impact

Set up:

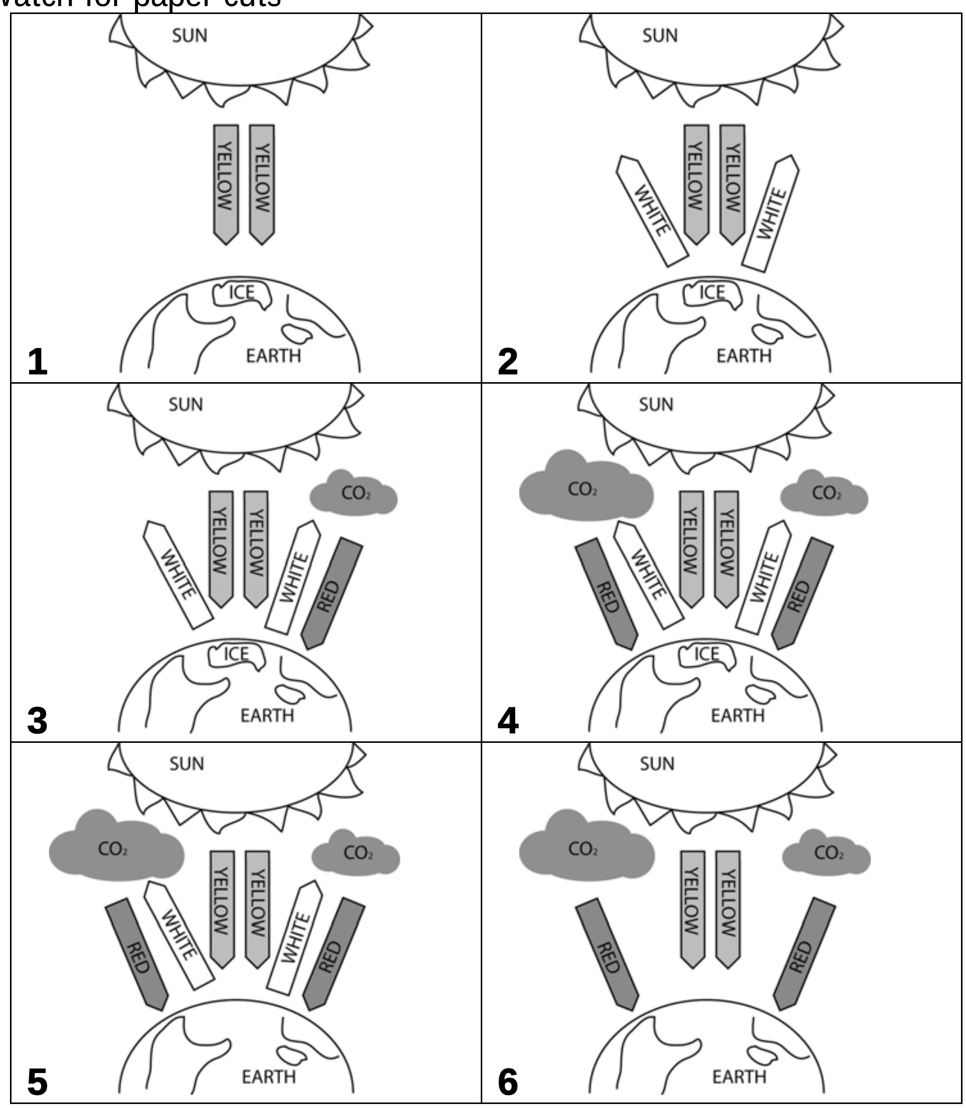
Have these signs available: Earth, ice cap, sun, two sun arrows, two ice-reflection arrows, two CO_2s, and two CO_2 absorption arrows.

How to:

Follow the script and diagram for the order of placing the signs on the board.

Safety:

Watch for paper cuts



Works Consulted

An Inconvenient Truth. Dir. Davis Guggenheim. Perf. Al Gore. Paramount Pictures. 2006.

Hocking, Colin, Cary Sneider, John Erickson, and Richard Golden. *Global Climate Change and the Greenhouse Effect*. LHS GEMS. Berkeley: Lawrence Hall of Science, University of California at Berkeley, 1990.

National Research Council. *National Science Education Standards*. Washington DC: National Academy Press, 1996. *The National Academies Press Website*. Ed. National Academy of Sciences. 2005. 21 December 2005 <http://books.nap.edu/html/nses/6a.html>.

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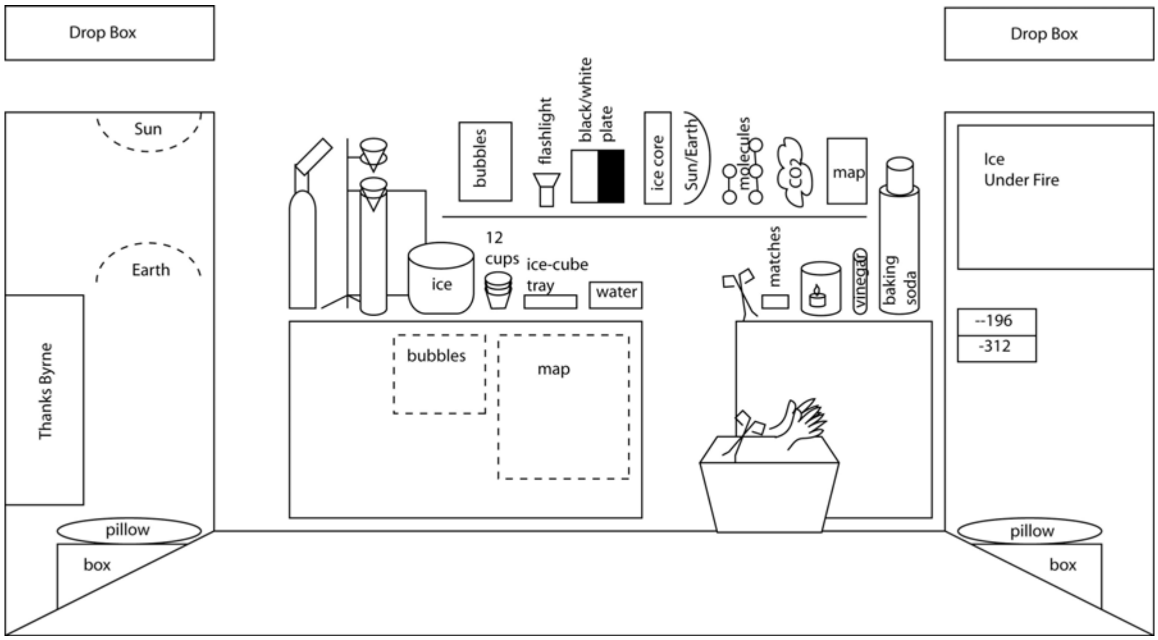
Appendix A – Sample Stage Layout

Stage Layout



To Do Ahead Of Time:
Get LN_2
Get Ice

Appendix B – Materials

Materials to Fabricate

There are many possible signs & graphic elements. Use or not, as suits your institutions traditions.

Sea Level Rise Maps:

Visit the website below to see a variety of options for maps:

http://www.geo.arizona.edu/dgesl/research/other/climate_change_and_sea_level/sea_level_rise/sea_level_rise.htm

Contact Jeremy Weiss or Jonathan Overpeck for permission to use these maps. Contact information is on the website.

Drop Boxes for solutions

If possible, create drop boxes that will release long scrolls with solutions at the end of the demonstration. It adds to the energy and fun of the program. These boxes can be built by exhibits team with a trap door on the bottom, held by a latch & controlled by a pull wire. The scrolls are hung at the top of the box, rolled up, and stored inside until released. The bottom of the scrolls may be attached to simple PVC

Model ice core.

Hazardous Materials Used in the Demonstration

LN_2
Propane torch
Matches

Consumable Supplies (per show)

	Item	Description	Quantity
❑	Water	A few liters of water	2 liters
❑	Ice	1 liter of ice cubes	1 liter
❑	Red food coloring	1 drop	1 drop
❑	Blue food coloring	2 drops	2 drops
❑	LN_2	To freeze water	¼ dewar
❑	Clear Plastic Cups	Cups to hold ice – 12 total used per demonstration, some break	2 used up per demo
❑	Tape	Brightly colored tape	3 inches
❑	Candles	2 votive candles	2 per 20 demos
❑	Matches	Strike-anywhere matches	2-4
❑	Baking Soda	To make CO_2	3 Tbsp
❑	White Vinegar	To make CO_2	10 mL
❑	Batteries	Depends on flashlight	1-2
❑	Propane	Propane cylinder for torch	No idea

Durable Supplies

	Item	Description	Quant.
❑	Thank-you sign	Thanks to supporters or advisors	1
❑	Sun-Earth Feltboard	Brightly Colored Signs: Sun, Earth, Ice Cap, 2 sun arrows, 2 ice arrows, 2 CO_2 clouds, 2 CO_2 arrows.	1
❑	Propane torch	Self-lighting torch	1
❑	Ice bucket	Clear ice bucket	1
❑	Ring Stand	1-meter-tall ring stand, with ring	1
❑	Huge Graduated Cylinder	A ½-meter-tall graduated cylinder – 10 cm in diameter	1

❑	Mesh cone	Bend a mesh pizza pan into a cone	1
❑	Funnel	Funnel to sit in the graduated cylinder	1
❑	Map	Map of your region with 6m ocean rise	1
❑	Plastic Cups	12 per demonstration – 10 are reusable	1
❑	Silicon ice-cube tray	A flexible silicone ice-cube tray that can stand up to LN_2.	1
❑	Tupperware	A shoe-box sized Tupperware to hold room-temp water to fit the ice-cube tray.	1
❑	Bubbles sign	A blown-up image of microscopic bubbles in ice	1
❑	Black/White Sign	A sign that is have black & half white. Could be made of Sintra.	1
❑	Flashlight	A flashlight bright enough to see in the stage light	1
❑	Ice Core	A model of an ice core	1
❑	O_2 Model	Two racquetballs on a stick.	1
❑	CO_2 Model	Three racquetballs on a flexible stick.	1
❑	Tongs	Tongs for holding lit matches	1
❑	Tongs	Tongs for holding ice in LN_2	1
❑	Beaker	A plain ~500mL beaker	1
❑	Graduated Cylinder	A plain ~75mL graduated cylinder	1
❑	Turkey Baster	A regular turkey-baster or a pipette	1
❑	Flask	A flask with a narrower neck than body	1
❑	LN_2 gloves	A pair of cryogenic gloves	1 pair
❑	LN_2 Temp Signs	Signs for the temp of LN_2 (C^o, F^o)	1
❑	Ice Under Fire	Demonstration Sign	1
❑	Drop Scrolls	Drop scrolls with suggested solutions	2
❑	Drop Boxes	Drop boxes rigged to drop the scrolls	2
❑	Fire Extinguisher	For safety	1

Appendix C – Educational Standards Addressed

General National Education Standards Supported Science Standards (National Research Council 1996)

These are standards addressed, but not taught thoroughly in this demonstration.

Physical Science

- Properties and changes of properties in matter (5-8)
- Transfer of Energy (5-8)
- Interactions of energy and matter (9-12)

Science in Personal and Social Perspectives

- Changes in environments (K-4)
- Environmental quality (9-12)
- Natural and human-induced hazards (9-12)
- Science and technology in local, national, and global challenges (9-12)

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Appendix D – Expansions

Molecule Activity

Jim Callahan of Climate Change Education mentioned this expansion suggested by Paul Dougherty from Exploratorium.

Using this CO2 model, we can actually show (at a high school or college introductory physics level) how the molecule behaves under different wavelengths.

If the molecule encounters visible light or higher-energy waves (x-rays, gamma rays) you jiggle the center molecule fast but not far. The top and bottom atoms will only quiver, but they will quiver.

When hit by radio waves – really low-energy waves – you can move the molecule slowly in big sweeps – all three move in unison.

But, when you hit the molecule with infrared waves (IR), you hit the CO_2 with its resonant frequency. Move the molecule fast and hard so you get big wiggles on the end molecules. This is just like pushing a kid on a swing – when you get it right, you swing higher and higher.

Doesn't matter what frequency you hit the O_2 and N_2 – they're too rigid – there isn't a resonance.

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Molecular Friends

Call up a (friendly) pair of volunteers to be an oxygen molecule. With their arms tightly wrapped around each other, have them jump up and down.

Call up three more volunteers. Holding hands only, have them jump up and down. You can direct them to jump at different times. You'll see the same effect: three loosely bound is wigglier than two tightly bound.

Alternative to Drop Scrolls

Print solutions on sheets of paper (like fortune cookies, but bigger). Toss a big pile into the audience, and have them pick them up and read a few.

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Appendix E – Myth Busting Myth Busters

Myth Busting Myth Busters on Global Climate Change

By Jeremy Higgins, Pacific Science Center Teacher, 2007

The main questions are taken from this site:

http://peakoildesign.com/blog/peakengineer/global_warming_myths_and_lies

1. Mars is undergoing global warming, therefore humans cannot be causing it on Earth.

Short answer: We can't really make assumptions about our atmospheric conditions based on the Martian atmosphere.

No. Mars is not undergoing global warming. The Mars Global Surveyor detected a decrease in the mass of the South Polar Cap between 1999 and 2005. First, this is a regional (not global) warming localized to the south pole of mars. There is no similar data for any corresponding temperature change at either the north pole or any other part of Mars. Secondly, since a Martian year is 687 days, this represents only 3 data points, which does not equate to the long-term trend we see on Earth. (Indeed, we see dramatic peaks and valleys in the yearly temperature data on Earth.) Lastly, research has shown that Mars' climate is far more volatile than our own, and is quite sensitive to changes in dust storm activity and orbital variations. If most of the planets and moons in the solar system were exhibiting warming trends, *that* would be a valid point for argument.

2. Volcanoes release much more carbon dioxide than humans.

Short answer: Volcanoes would be more likely to lead to a cooling effect.

No. Volcanic activity is 0.02 to 0.05 Giga-tons/year. [Note: 1 Peta-gram (PgC) = 1 Gigaton (Gt)] Humans produce 8 Gt/yr (and climbing). Volcanoes elicit a far more dominating cooling effect due to atmospheric dispersal of particulates and sulfur dioxide. In addition, there has been no recent increase in volcanic activity – and the volcanic activity we have seen has actually slowed global warming.

3. The Earth (and its carbon cycle) is too big for humans to affect it.

While the Earth exchanges a great deal of carbon between the ocean, atmosphere, soil, and biosphere, it is the net balance which is of greatest concern to us. Without human influence, this regulatory process produces a net carbon increase of 0.0 Gt/year. During 1850-2000, through a combination of fossil fuel burning, cement manufacturing, and land-use changes, humans added a *net* 174 Gt of carbon. This caused the majority of an increase from 288 ppm (parts per million) to 369.5 ppm of CO_2. As mentioned above, we currently add 8 Gt/year to the atmosphere.

4. The sea level has not changed.

Short answer: The data we have say otherwise.

Yes, it has. Since 1900, sea level has risen by about 35 cm (13.8 inches). This change in sea level is accelerating.

5. Scientists predicted imminent global cooling in the 1970s.

Short answer: Scientific publications did not make this prediction.

No, they did not. Some magazines reported it as such, but scientists understood that their preliminary, localized, and uncertain measurements could not be extrapolated to either the world or a long-term trend. They *did* indicate that the potential for an ice age in the next 20,000 years was possible, but they made no predictions. Climate science has advanced tremendously in the intervening years, as has the data, and the conclusions for our climate are far more certain.

From Realclimate.org:

> *There were some regrettable things published in the popular press (e.g. Newsweek; though National Geographic did better). But we're only responsible for the scientific press.*
>
> *Where does the myth come from? Naturally enough, there is a kernel of truth behind it all. Firstly, there was a trend of cooling from the 40's to the 70's (although that needs to be qualified, as hemispheric or global temperature datasets were only just beginning to be assembled then). But people were well aware that extrapolating such a short trend was a mistake (Mason, 1976) . Secondly, it was becoming clear that ice ages followed a regular pattern and that interglacials (such as we are now in) were much shorter that the full glacial periods in between. Somehow this seems to have morphed (perhaps more in the popular mind than elsewhere) into the idea that the next ice age was predictable and imminent. Thirdly, there were concerns about the relative magnitudes of aerosol forcing (cooling) and CO_2 forcing (warming), although this latter strand seems to have been short lived.*

6. Scientists get paid big bucks to skew their data to indicate Global warming.

No, they don't. There is little commercial funding available for research designed to support global warming. It is far more lucrative to produce research denying global warming. With little exception, funding for climate research is provided by governments, which do not attach conditions to the results of the research. Logically, of course, it doesn't make sense that corporations or governments would want to fund skewed studies that indicate their entire way of living is threatening the planet. And with tens of thousands of scientists producing research indicating human-induced global warming, the task to compromise the ethics of so many esteemed professionals would be, to say the least, challenging.

7. Variations in solar output cause global warming

Short answer: The Sun is not the sole creator of change in climate.

While global warming could not occur without solar influx, the sun's output has been relatively stable for as long as we've studied it, and has in fact been declining in recent years. Solar variability plays a very small role, if any, in global warming.

8. All temperature data is suspect due to the urban heat island effect.

Short answer: Temperature measurements are taken in various places, the measurements all agree.

That argument might be valid if all measurements were taken in the heart of cities. But they aren't. Thermometers in the middle of the arctic, in barren deserts, in the middle of oceans, on top of mountains, and deep in the wilderness all agree on a global temperature rise. Unless you believe that the urban heat island effect can affect satellites, this claim is clearly wrong.

9. Because it snowed a great deal and got very cold in some areas, Global warming is not happening.

Short answer: Global warming predicts many different changes in weather patterns.

First, increased precipitation is predicted by global warming. Increased snowfall events are further evidence of global warming, not proof against it. Second, regional temperature variations occur. It is the global average temperature which is of greatest concern. And third, temperatures vary. Even record cold global temperatures for an entire year would not be out of step with global warming. Global warming is about the long-term average trend.

10. It is not possible to distinguish the effects of human activities from natural processes with regard to CO2.

Short answer: Human impact is the one thing we have the best ability to measure.

That is not true. We know how much CO2 is produced from burning a barrel of oil and we know how many barrels of oil we use. Similarly, we know how much CO2 certain types of plants absorb and we have solid estimates for how many of each type of plant exist. The same goes for volcanoes, the ocean, and the soil. It

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is a matter of collecting this data, which is the task undertaken by hundreds of scientists. Estimates vary, but they all agree on one point -- humans are causing global warming.

11. Doesn't global dimming reduce the amount of sunlight reaching the Earth, therefore reducing the temperatures?

Short answer: Maybe. It's not a well researched field. Even an increase in greenhouse gases known to increase temperature would reduce the amount of sunlight reaching the Earth. It's also important to note that the sunlight is still reaching the upper atmosphere.

From Realclimate.org

> *Global dimming is indicated by measurements over land areas in many regions in the world and may therefore be a real phenomenon. Though there are serious issues with the quality of some of the data (birds drinking out of uncovered evaporation pans, drift and inhomogeneities in the solar radiation measuring instruments), in the most global assessment, Beate Liepert estimated that there was globally a reduction of about 4% in solar radiation reaching the ground between 1961 and 1990. While more recent indications are that the trend may have reversed in the last decade, it could still be significant. Assuming for the sake of argument that these data are valid, what could have caused this? A change of that magnitude in the incoming solar radiation itself is not possible since satellite observations would have seen it. Thus, it must be something that is happening in the atmosphere to intercept solar radiation. There are only a few possibilities: clouds, water vapour or aerosols.*
>
> *First of all it is important to note that even pure greenhouse gas forcing will lead to a slight decrease in surface solar radiation (due to the concurrent increased.*