Today I Learned About Planes

"A lot of climate science is difficult because we don't have a spare planet to do a control experiment on and that makes life much harder. (So, if we could create one, that would be ideal.) But failing our ability to do that, we've got to approach problems in a more piecewise way. That means building up models from rigorously verified pieces of evidence."

Professor Steven Barrett, MIT Laboratory for Aviation, and the Environment

TILclimate podcast: Today I Learned About Planes

Albedo

The *albedo* of a surface is its ability to reflect light. A surface with a high albedo reflects most of the sun's light back out into space. A surface with a low albedo absorbs energy from the sun and heats up. Think about a paved road or parking lot in the summer. A dark surface has a very low albedo, and it quickly becomes too hot to walk on barefoot. A light-colored surface will not get as hot because it is reflecting more of the sun's energy away.

On the surface of the Earth, entire regions have a high or low albedo. In this demonstration, you will test which surfaces reflect or absorb the most heat.

Predictions

You will be heating three surfaces equally with incandescent bulbs: dark soil, light sand, and water. Then, you will turn the heat off and measure how they cool down.

1. Which do you think will heat up the fastest?
2. Which do you think will get hottest overall?
3. Which do you think will cool down the fastest?

Questions

1. Which heated up the fastest?
2. Which got hottest overall?
3. Which cooled down the fastest?
4. In the podcast episode, we learn that temporary clouds from airplanes (condensation trails or "contrails") can reflect the sun's energy if they are over dark areas with low albedo, and act like a jacket trapping heat if they are over light areas with high albedo or at night. How could you model this effect in this demonstration?
5. At a global scale, how do you think different surfaces affect how heat is trapped by the carbon dioxide blanket around Earth? Visit https://neo.gsfc.nasa.gov/ and click on albedo to see how albedo varies around the globe and throughout the year.

Today I Learned About Planes

Data Table

Time (in minutes)	Dark Soil Temp	Light Sand Temp	Water Temp
0:00			
TURN ON LAMP(S)			
1:00			
2:00			
3:00			
4:00			
5:00			
6:00			
7:00			
8:00			
9:00			
10:00			
TURN OFF LAMP(S)			
11:00			
12:00			
13:00			
14:00			
15:00			
16:00			
17:00			
18:00			
19:00			
20:00			

Instructions:

1. Place a thermometer in each container.
2. Position lamp(s) equally over all three containers.
3. Leave the thermometer in the container – do not remove it to take readings.
4. Take first reading before turning on lamp(s).
5. Take one reading every minute for 10 minutes. (Do not stop stopwatch between readings.)
6. Turn off the lamp(s).
7. Take one reading every minute for 10 minutes. (Do not stop stopwatch between readings.)
8. Graph your results.

Today I Learned About Planes

"CO_2 has a lifetime [in the] atmosphere of hundreds of years. Now most of the CO_2 that aviation's ever emitted is still in the atmosphere because it lasts so long... And so we're now experiencing the warming from all that accumulated CO_2."
Professor Steven Barrett, MIT Laboratory for Aviation, and the Environment
TILclimate podcast: Today I Learned About Planes

A Warming Planet

Carbon dioxide (CO_2) acts like a blanket around Earth, trapping heat. A regular amount of heat-trapping CO_2 is important for life on Earth. As we burn fossil fuels like oil, coal, natural gas, and jet fuel, and cut down forests, we release rampant CO_2 into the atmosphere, trapping much more heat. This trapped heat is causing dramatic changes to the world's climate, including more intense storms, droughts, and other impacts.

Why Carbon Dioxide?

CO_2 is not the only heat-trapping gas. So why do scientists focus on it? In the next activity, you will answer this question. All heat-trapping gases work by reflecting infrared radiation (heat) back to the surface of Earth instead of letting it radiate into space. But different gases have different qualities: Some trap a lot of heat, while others only trap some; some gases remain in the atmosphere for centuries, while others are cycled back down to Earth in a short time; and some we emit a lot of, while others are less common.

To make calculations easier, all heat-trapping gases can be converted to *carbon dioxide equivalents* (often written CO_2e or CO_2-eq). Below are the CO_2e values for the most important heat-trapping gases, as well as how long they stay in the atmosphere.

Gas	CO_2E	Life in Atmosphere
Carbon dioxide (CO_2)	1	100-1,000 years
Methane (NH_4)	25	10-15 years
Nitrous Oxide (N_2O)	298	100-150 years
Fluorocarbons (FCs)	up to 12,690	Weeks to thousands of years

Today I Learned About Planes

Heat Trapped* by Selected Gases

Year	Carbon dioxide	Methane	Nitrous oxide	FCs	Other gases
1979	1.027	0.406	0.104	0.132	0.031
1980	1.058	0.413	0.104	0.139	0.034
1981	1.077	0.42	0.107	0.146	0.036
1982	1.089	0.426	0.111	0.153	0.038
1983	1.115	0.429	0.113	0.161	0.041
1984	1.14	0.432	0.116	0.168	0.044
1985	1.162	0.437	0.118	0.176	0.047
1986	1.184	0.442	0.121	0.185	0.049
1987	1.211	0.447	0.12	0.193	0.053
1988	1.25	0.451	0.122	0.204	0.057
1989	1.275	0.455	0.126	0.212	0.061
1990	1.293	0.459	0.129	0.219	0.065
1991	1.312	0.463	0.131	0.224	0.069
1992	1.323	0.467	0.133	0.229	0.072
1993	1.334	0.467	0.134	0.231	0.074
1994	1.356	0.47	0.135	0.232	0.076
1995	1.383	0.472	0.136	0.235	0.077
1996	1.41	0.473	0.139	0.236	0.078
1997	1.426	0.474	0.142	0.237	0.079
1998	1.464	0.478	0.144	0.238	0.08
1999	1.495	0.481	0.148	0.238	0.082
2000	1.513	0.481	0.151	0.238	0.083
2001	1.535	0.48	0.153	0.238	0.085
2002	1.564	0.481	0.155	0.238	0.087
2003	1.6	0.483	0.157	0.237	0.089
2004	1.627	0.483	0.159	0.237	0.09
2005	1.655	0.482	0.162	0.235	0.092
2006	1.685	0.482	0.165	0.235	0.095
2007	1.71	0.484	0.167	0.233	0.098
2008	1.739	0.486	0.17	0.232	0.1
2009	1.76	0.489	0.172	0.231	0.103
2010	1.791	0.491	0.175	0.229	0.106
2011	1.817	0.492	0.178	0.228	0.109
2012	1.845	0.494	0.181	0.227	0.112
2013	1.882	0.496	0.183	0.225	0.114
2014	1.908	0.499	0.187	0.224	0.117
2015	1.938	0.504	0.19	0.223	0.119
2016	1.985	0.507	0.193	0.221	0.122
2017	2.013	0.509	0.195	0.22	0.124
2018	2.044	0.512	0.199	0.219	0.127
2019	2.076	0.516	0.202	0.218	0.129

Data from US EPA "Climate Change Indicators: Climate Forcing"
https://www.epa.gov/climate-indicators/climate-change-indicators-climate-forcing

The US Environmental Protection Agency (EPA) collects data on the amount of heat trapped by various gases in the atmosphere.

1. Graph the data.
2. Which gas contributes the most to heating?
3. In 2019, each of these gases made up a percentage of total emissions from the US:

Gas	% Emissions
Carbon dioxide	80.14
Methane	10.05
Nitrous Oxide	6.97
FCs	2.83

4. Why do you think climate scientists and communicators focus on carbon dioxide when talking about climate change?

*The heat trapped by a gas is called *radiative forcing* and is measured in watts per square meter. For more on radiative forcing, read https://climate.mit.edu/explainers/radiative-forcing

Today I Learned About Planes

"The current forecasts are that aviation would double or triple by mid century, and at the same time most scientists say that you want to reduce CO_2 emissions by about 80%. So even though today aviation's only about six per cent, if we want to reach something like an 80% or more reduction of CO_2 emissions, while enabling growth in aviation because of the positive effect it has on society, that creates a huge challenge that is very difficult to answer."
Professor Steven Barrett, MIT Laboratory for Aviation, and the Environment
TILclimate podcast: Today I Learned About Planes

The Future of Airplanes

Engineers, designers, and scientists are developing the future of air travel, and many of them are looking to reduce – or even eliminate – the need for fossil fuels in airplanes. Each member of your group will read one article and then summarize for the other members. You do not need to understand all the technology involved – the general story is enough.

Questions

1. How would this new technology help reduce CO_2 emissions from airplanes?
2. When do you think this technology might be in use?
3. What is your favorite part of the story?

Discussion

Have each member of your group share their answers to the questions above.

Discuss:

- Which of these technologies seem the most promising?
- Are there any of these technologies that could be combined?
- If you worked for an airplane company, which of these technologies would you be the most excited about?

Today I Learned About Planes

Articles

- NASA Tests Machine to Power the Future of Aviation Propulsion https://www.nasa.gov/aeroresearch/nasa-tests-machine-to-power-the-future-of-aviation-propulsion
- Fantasy to Reality: NASA Pushes Electric Flight Envelope https://www.nasa.gov/feature/glenn/2020/fantasy-to-reality-nasa-pushes-electric-flight-envelope
- Sustainable Aviation Fuels from Low-Carbon Ethanol Production https://www.energy.gov/eere/bioenergy/articles/sustainable-aviation-fuels-low-carbon-ethanol-production
- Airbus reveals new zero-emission concept aircraft https://climate.mit.edu/ed/airbus
- MIT and NASA engineers demonstrate a new kind of airplane wing https://news.mit.edu/2019/engineers-demonstrate-lighter-flexible-airplane-wing-0401
- MIT engineers fly first-ever plane with no moving parts https://news.mit.edu/2018/first-ionic-wind-plane-no-moving-parts-1121
- Concept for a hybrid-electric plane may reduce aviation’s air pollution problem https://news.mit.edu/2021/hybrid-electric-plane-pollution-0114