Today I Learned About Planes

Description:

How much of an impact does air travel have on climate change? What can be done about it? Through a hands-on demonstration and a short literature review, students consider the impacts and future of aviation. With data, students consider why climate communicators and scientists focus on carbon dioxide.

Skills & Objectives

SWBAT

- Understand that dark surfaces absorb more of the sun's energy than light surfaces.
- Explain why carbon dioxide is a focal heat-trapping gas.
- Understand a few promising technologies for the future of aviation.

Skills

- Data collection & graphing
- Interpreting science writing aimed at the general public

Students Should Already Know That

- Airplanes burn jet fuel, a fossil fuel that releases carbon dioxide (CO_2) as a byproduct.
- Airplanes also leave narrow temporary clouds behind, called contrails.

Standards Alignment:
HS-ESS2-4 Use a model to describe how variations in the flow of energy into and out of Earth's systems result in changes in climate.
HS-ESS3-4 Evaluate a technological solution that reduces impacts of human activities on natural systems.
HS-ETS1-3 Evaluate a solution to a complex real-world problem

Disciplinary Core Ideas:
ESS2.A Earth Materials and Systems
ESS2.D Weather and Climate
ESS3.C Human Impacts on Earth Systems
ESS3.D Global Climate Change

Today I Learned About Planes

How To Use These Activities:

Pages with the circular "TILclimate Guide for Educators" logo and dark band across the top are intended for educators. Simpler pages without the dark band across the top are meant for students.

Each of the included activities is designed to be used as a standalone, in sequence, or integrated within other curriculum needs. A detailed table of contents, on the next page, explains what students will do in each activity.

A Note About Printing/Materials

All student pages are designed to be printable in grayscale, except for the maps on page 4. A few copies of this page could be printed color for students to share, or the image projected in the classroom.

The worksheets do not leave space for students to answer questions. Students may answer these questions in whatever form is the norm for your classroom – a notebook, online form, or something else. This allows you, the teacher, to define what you consider a complete answer.

Materials for the Albedo Demonstration are listed on a separate page.

Podcasts in the Classroom: Throughout these Guides for Educators, we invite students to think about how they would share their learning with family and friends. One way to do this is to encourage your students to create their own podcasts - they're shareable, creative, and have multiple options for embedded assessment. We would love to hear any podcasts or see any other projects you or your students create! Email us at tilclimate@mit.edu, Tweet us @tilclimate, or tag us on Facebook @climateMIT.

Today I Learned About Planes

Detailed Table of Contents

Today I Learned About Planes

Planes, Clouds, and Climate

This Educator Guide includes a demonstration, a map-reading exercise, and an article review. Educators may pick and choose among the pieces of the Guide, as suits their class needs.

Parts of this Guide may align with the following topics:

- Physical science: Albedo, cloud formation, atmospheric levels
- Life/environmental science: Impacts of climate change on ecosystems
- History/social science: Impact of flight on international relations, travel, etc.
- ELA/nonfiction: Reading scientific articles for content, argument, and connection.

MIT Resources

We recommend the following as resources for your own better understanding of climate change or as depth for student investigations. Specific sections are listed below:

- Climate Science, Risk & Solutions, an interactive introduction to the basics of climate change. https://climateprimer.mit.edu/
  - Chapter 02 The greenhouse effect and us
  - Chapter 02b Our atmosphere
  - Chapter 06 Predicting climate
  - Chapter 09 How long can we wait to act?
  - Chapter 10 What can we do?
- MIT Climate Portal Explainers are one-page articles describing a variety of climate topics. https://climate.mit.edu/explainers
  - Aviation
  - Climate Models
  - Greenhouse Gases
  - Radiative Forcing
  - Biofuel

Today I Learned About Planes

Wrap-Up Discussion Questions

- In the podcast episode, we learn that temporary clouds produced by 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 during the night. How could you model this effect in the lamp demonstration?
- Airplanes help families connect, people experience the world, and businesses grow in new ways. How can we reap the benefits of air travel while reducing or eliminating CO_2 emissions? You could list technological, behavioral, or other kinds of solutions.
- Why do we focus on carbon dioxide as the main heat-trapping gas?
- How could governments, businesses, and decision-makers change air travel’s impact on climate change?

Climate Solutions

Climate solutions can be thought of as falling into four categories outlined below. Across all categories, solutions at the community, state or federal level are generally more impactful than individual actions. For example, policies that increase the nuclear, solar and wind mix in the electric grid are generally more effective at reducing climate pollution than asking homeowners to install solar panels. For more on talking about climate change in the classroom, see “How to Use This Guide”.

- **Energy Shift**
  How do decision-makers make the switch from carbon-producing energy to carbon-neutral and carbon-negative energy?
- **Energy Efficiency**
  What products and technologies exist to increase energy efficiency, especially in heating and cooling buildings?
- **Adaptation**
  How can cities and towns adapt to the impacts of climate change?
- **Talk About It**
  Talking about climate change with friends and family can feel overwhelming. What is one thing you have learned that you could share to start a conversation?

What solutions are the most exciting in your classes? We would love to hear from you or your students! Images, video, or audio of student projects or questions are always welcome. Email us at tilclimate@mit.edu, Tweet us @tilclimate, or tag us on Facebook @climateMIT.

Today I Learned About Planes

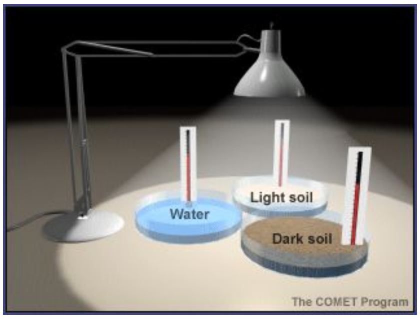
Albedo Demonstration: Materials

- Incandescent lamp(s) that can point down at a table
- Three identical pie pans or dishes
- Dark-colored potting soil
- Light-colored sand, perlite, sugar, or salt (any light-colored particulate)
- Water
- Three thermometers that can be read while left in the containers
- Timer
- Graph paper, chart-pack, whiteboard, or simple graphing computer program
- Three colors of colored pencils, markers, etc.

Albedo Demonstration: Setup

This demonstration can be set up for a whole class, or groups can run multiple copies of the demonstration simultaneously. For multiple stations, multiply supplies as needed.

- Pour equal depths of dark potting soil, light material, and water into three equal-sized dishes, pie pans, or similar.
- Ideally, leave containers out overnight so that all materials are at the same starting room temperature.
- Set up incandescent reflector lamp(s) over containers. You may set up three lamps (one equally over each surface) or one lamp equally over all three. Make sure that lamps are identical, have the same wattage of bulb, and are the same distance above each surface. Do <u>not</u> turn lamp(s) on.



- Put one thermometer into each substance. Depending on the type of thermometer, this could be just below the surface or stuck upright in the substrate. The thermometers should be readable without removing them from the substrate. Digital aquarium thermometers ($8-15 online) are ideal for this, but other thermometers will work well.

Albedo Demonstration: Data Collection & Graphing

Students can collect data on the included chart individually, in groups, or as a whole class. Since measurements are taken once per minute for 20 minutes, one group of students could be collecting data while others are doing a different activity.

Data is collected with the lamp on for the first 10 minutes after getting an initial starting temperature. Then the lamp is turned off, and data is collected for a further 10 minutes.

Depending on your goals, you may graph the results individually, as a whole class, or in groups. Graph paper, chart pack, a whiteboard, or a simple graphing program may be used.

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"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.

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"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