Today I Learned About Geoengineering

Description:

Geoengineering includes a host of technologies and practices that seek to reduce the amount of heat trapped in Earth's atmosphere. Some of these technologies could have significant side effects that are not well understood. Who decides when or how to engineer the Earth's atmosphere?

Skills & Objectives

SWBAT

- Describe some key geoengineering technologies
- Understand some of the potential benefits and concerns about geoengineering

Skills

- Reading and discussing scientific writing
- Science communication

Students Should Already Know That

- The heat that is trapped by CO_2 and other heat-trapping gases in Earth's atmosphere is the heat of the sun.

Standards Alignment:
HS-ESS2-2 Analyze geoscience data to make the claim that one change to Earth's surface can create feedbacks that cause changes to other Earth systems.
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-ETS1-1 Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions.
RST.11-12.2 Determine the central ideas or conclusions of a text; summarize complex concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms.

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

TILclimate
Guide for Educators

Today I Learned About Geoengineering

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

All student pages are designed to be printable in grayscale, except for the map and graph on page 1. A few copies of the next 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.

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.

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Detailed Table of Contents

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Geoengineering

This Educator Guide includes a reading and a discussion. 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: atmospheric chemistry, aerosols, and atmospheric layers
- Life/environmental science: impacts of atmospheric chemistry on living systems
- History/social science: ethics and international decision-making
- ELA/literature: connections to terraforming science fiction
- ELA/nonfiction: explaining and discussing complex scientific topics

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 05 How much of the CO_2 increase is natural?
    Chapter 06 Predicting climate
    Chapter 07 Understanding risk
    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

    Soil-based Carbon Sequestration
    Forests and Climate Change
    Climate Models
    Greenhouse Gases
    Radiative Forcing
    Carbon Capture

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Wrap-Up Discussion Questions

- What are some of the possible benefits of geoengineering?
- What are some of the concerns with geoengineering?
- What questions do you still have? How might you answer these questions?
- Some people have suggested that discussing and researching solar radiation management could slow down progress on reducing CO_2 emissions. What do you think?
- If the science became clear that solar radiation management was possible, who should decide whether to do it?
- Who needs to know about the possibilities and challenges of geoengineering?

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.

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"The volcano erupts and lots of gases and rocks and dust and everything else escape, including so-called sulfur aerosols that reflect sunlight back into space and cool the temperature of the Earth. And in fact, after a major volcanic eruption like … Mount Pinatubo in the Philippines, the world could measure that the global temperature went down by about a half a degree."

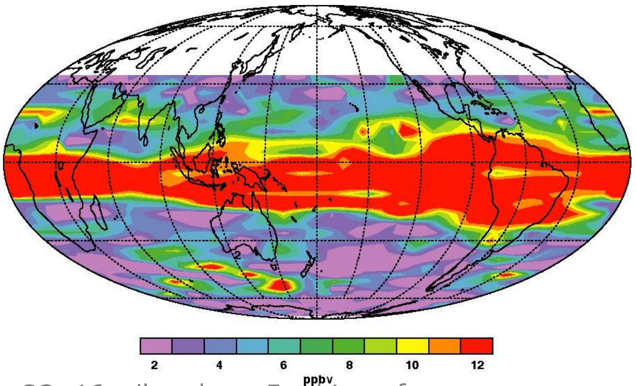
Janos Pasztor, Carnegie Climate Governance Initiative

TILclimate podcast: Today I Learned About Geoengineering

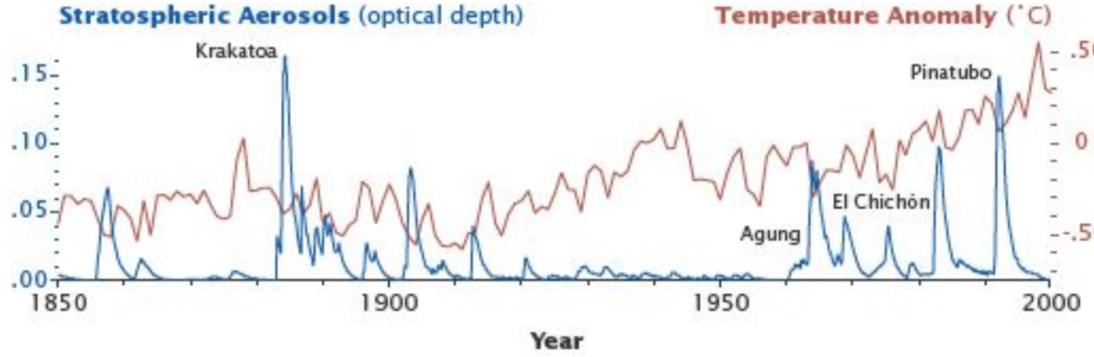
Volcanoes and a Cooling Earth

On June 15, 1991, a volcano in the Philippines called Mt. Pinatubo erupted. Over the next few days, the volcano spewed more than 20 million tons of sulfur dioxide (SO_2) into the atmosphere, along with millions of tons of ash, smoke, and other materials. In the atmosphere, SO_2 reacts to produce sulfate aerosols. Aerosols are extremely small particles that stay in the air. Sulfate aerosols have the effect of reflecting the sun's rays back into space, cooling Earth.

The sulfate aerosols from Mt Pinatubo spread around the globe, especially at the equator. Global temperatures dropped by 0.6ºC (1.1ºF) for the next two years, and then continued to rise on the same path they had been rising on before 1991. Looking back, climatologists could see a similar pattern after eruptions at El Chichón (Mexico, 1982) and Mt Agung (Indonesia, 1963.) The 1883 eruption of Krakatoa lowered global temperatures by 0.4 ºC (0.7ºF) and may have caused record rainfall in southern California, over 9,000 miles away.



SO_2 16 miles above Earth's surface
September 21, 1991
NASA Upper Atmosphere Research Satellite[1]

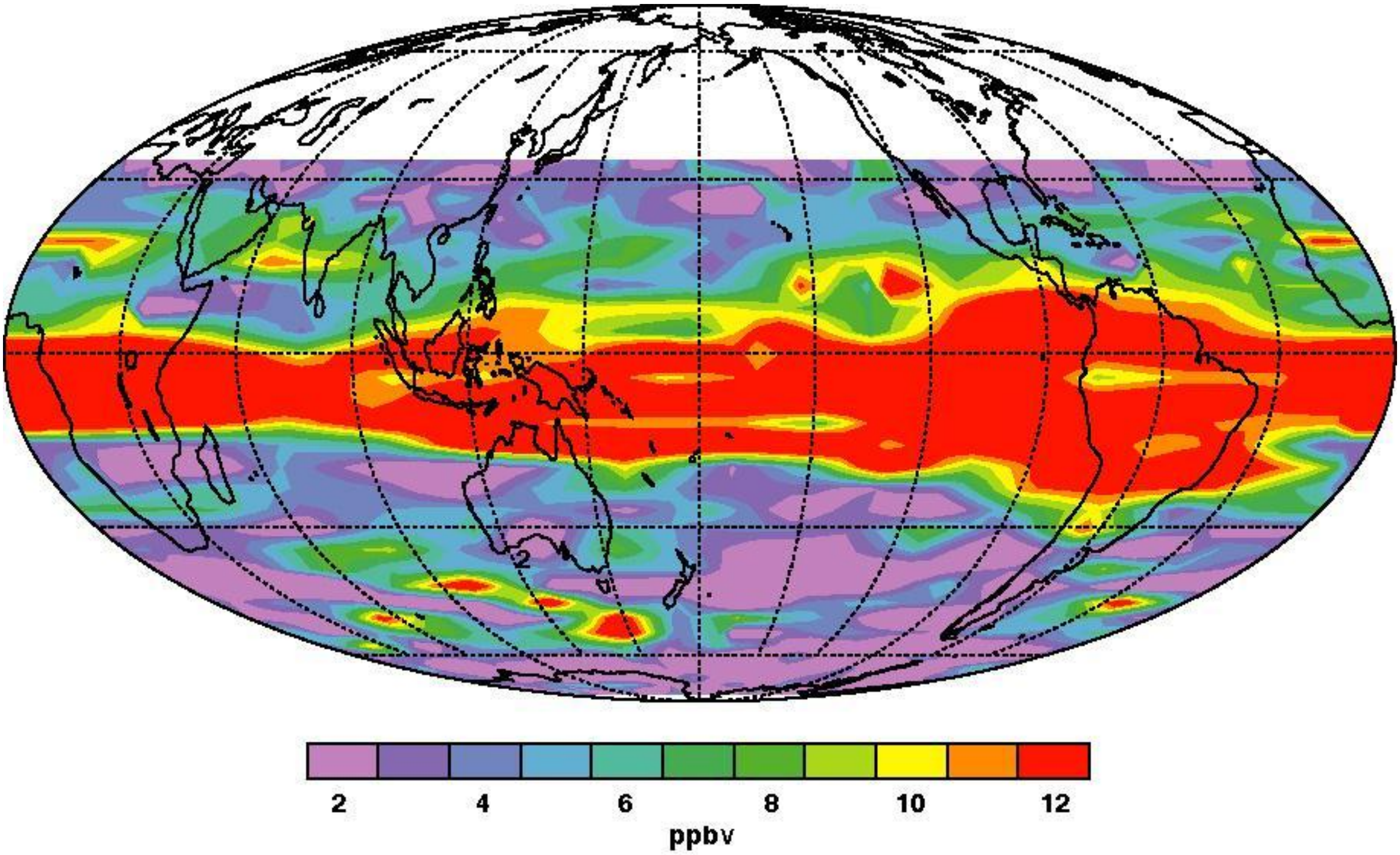


Aerosols in the high atmosphere from large volcanic eruptions align with drops in temperature.
https://earthobservatory.nasa.gov/features/Aerosols/page3.php

1 NASA Upper Atmosphere Research Satellite https://uars.gsfc.nasa.gov/uars-science/BrochurePage1.html

ENVIRONMENTAL SOLUTIONS INITIATIVE

Today I Learned About Geoengineering



SO_2 from Mt Pinatubo 16 miles above Earth's surface, September 21, 1991
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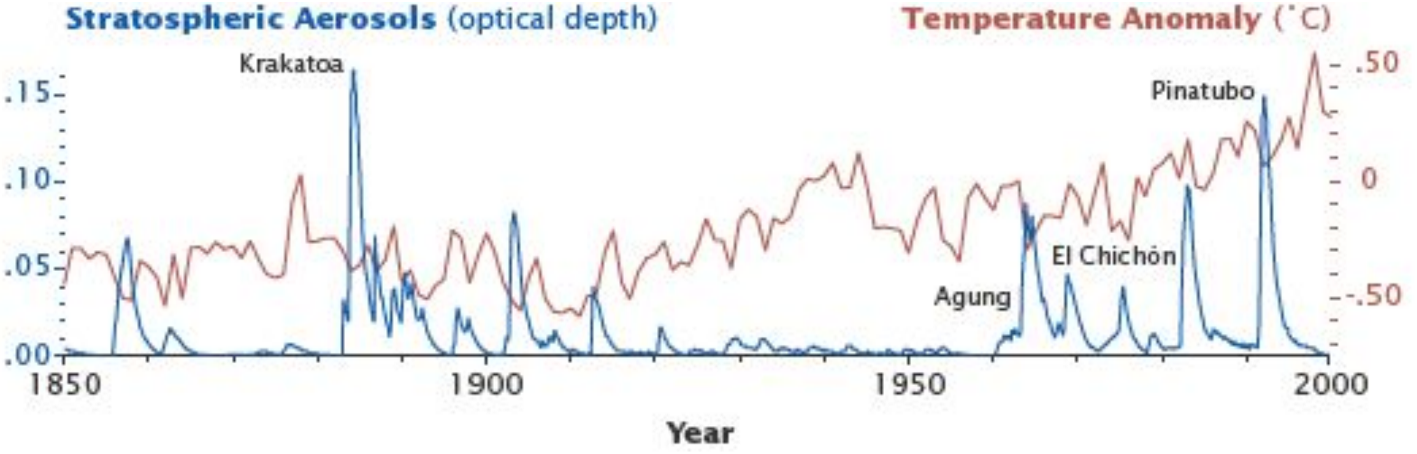

Aerosols in the high atmosphere from large volcanic eruptions align with drops in temperature.
https://earthobservatory.nasa.gov/features/Aerosols/page3.php

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"This technology also has impacts. First of all, it reduces sunlight that comes in to reach the Earth and that will have an impact on agriculture, on forests, on ecosystems. It will also change the weather patterns and we don't quite know how much but we need to find out before we take any decisions."
Janos Pasztor, Carnegie Climate Governance Initiative
TILclimate podcast: Today I Learned About Geoengineering

How Do We Decide? Who Decides?

Geoengineering – especially *solar radiation management* and/or *stratospheric aerosol injection* (see glossary, page 4) – has the potential to counteract decades of trapped heat in Earth's atmosphere. As we burn fossil fuels like coal, oil, and natural gas and cut down forests, we release carbon dioxide (CO_2) into the atmosphere. This CO_2 acts like a blanket, trapping heat from the sun – and this is warming our Earth, air, and ocean. Some people suggest that we should inject reflective particles called *aerosols* into the atmosphere to reflect the sun's heat back out into space.

But who is "we," and what, exactly, would that look like?

In small groups, each person or pair of people should read one of the following articles:

Earth's Energy Budget, NASA, https://climate.mit.edu/ed/energybudget

What is stratospheric aerosol injection, and why do we need to govern it?
Carnegie Climate Governance Initiative
https://www.c2g2.net/project/infographic-what-is-stratospheric-aerosol-injection-and-why-do-we-need-to-govern-it/

Simulated geoengineering evaluation: cooler planet, but with side effects, NOAA, https://research.noaa.gov/article/ArtMID/587/ArticleID/2756/Simulated-geoengineering-evaluation-cooler-planet-but-with-side-effects

As You Read

- What are three core takeaways from this article that you want someone else to know?
- What do you find confusing or hard to understand?
- What questions do you still have?
- Does this article seem to encourage or discourage geoengineering as a solution?

Today I Learned About Geoengineering

Each One, Teach One

After each person or pair has finished reading and discussing their article, share with the members of your group in the order that the articles were listed.

- What are three core takeaways that other people need to understand?
- What questions do you still have?

After each person or pair has shared, discuss:

- Can anyone answer any of the questions other people had, based on what they read?
- What new questions do you have? How might you answer these questions?
- What are some of the possible benefits of geoengineering?
- What are some of the concerns with geoengineering?
- Some people have suggested that discussing and researching solar radiation management could slow down progress on reducing CO_2 emissions. What do you think?
- If the science became clear that solar radiation management was possible, who should decide whether to do it?

Share Your Learning

Geoengineering is challenging to communicate about – it includes complex science, tough questions, and many unknowns. How could you explain one or two core ideas to a friend or family member? Consider the medium: a podcast episode, comic strip, story, song, video? Who needs to know about the possibilities and challenges of geoengineering?

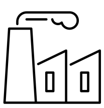
Today I Learned About Geoengineering

Glossary

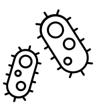
- **Geoengineering** is an umbrella term for a host of interventions that could reduce the amount of warming that Earth is experiencing due to heat-trapping gases in the atmosphere. There are two large categories of geoengineering: *Carbon Dioxide Removal* and *Solar Radiation Management*.

- **Carbon Dioxide Removal** is any technology, practice, or process that seeks to absorb carbon dioxide out of the atmosphere, reducing the amount of heat the atmosphere can trap. This includes:

  - **Forestation**, including *afforestation* (planting new forests) and *reforestation* (restoring and preserving existing forests). Trees absorb and store CO_2 as part of growth. Grasslands and other ecosystems also absorb CO_2.

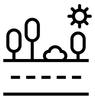


  - **Carbon Capture and Storage (CCS) technology**, including *CCS from fossil fuels* (capturing CO_2 from power plants and factories) and *CCS from air* (capturing CO_2 directly out of the air).



  - **Ocean Iron Fertilization** introduces iron into low-iron areas of the ocean, which causes *phytoplankton* (plant-like plankton) to grow. Phytoplankton absorb CO_2 as part of growth and store that CO_2 in the deep ocean when they die.

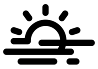
- **Solar Radiation Management** is any technology or process that seeks to reflect more of the sun's rays back out into space, reducing the amount of heat that enters Earth. These proposals range from technologies that are well-understood to ideas that still need significant research. This includes:



  - **Increased Albedo**, which makes roads, roofs, and other surfaces brighter to reflect more of the sun's rays.

  - **Cloud Seeding** would spray particles into low cloud areas (especially over oceans) to increase their brightness and reflect sunlight back into space.

  - **Cirrus Thinning** would break up high cirrus clouds, which otherwise tend to trap more heat on Earth.



  - **Stratospheric Aerosol Injection** would spray particles into the upper atmosphere, above the clouds, to reflect sunlight back into space.

  - **Space Mirrors** would orbit Earth and reflect the sun's rays.

Images from The Noun Project by Design Circle, Dooder, Lars Meiertoberens, Vichanon Chaimsuk, asianson.design, Gilad Sotil, and Michele Ficeli