Earth’s Energy Budget: A Story
Most of the energy on Earth comes to us from the Sun.

Did you know?: The amount of sunlight that reaches the Earth is equal to approximately 6 60w light bulbs for every square meter of the surface.
We can sense that energy in different ways. We see the things around us because of visible light...
... And we feel the heat from a campfire, which is infrared energy.
NASA senses the different types of energy too with satellite instruments.
If all of these types of energy from the Sun are always shining down on Earth, how does the Earth manage to maintain the perfect balance of energy – or equilibrium – that allows us to live and survive on Earth?

The Sun – hot though it is - is a tiny part of Earth’s environment. The rest is cold, dark space.
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The planet Mercury – too hot because it’s very close to the Sun

Average Surface Temperature
167 °C (~332 °F)
If all of these types of energy from the Sun are always shining down on Earth, how does the Earth manage to maintain the perfect balance of energy – or equilibrium – that allows us to live and survive on Earth?

The planet Mars – “too cold” because it is farther from the Sun and has a very thin atmosphere.

Average Surface Temperature
-65 C (~-85 F)
If all of these types of energy from the Sun are always shining down on Earth, how does the Earth manage to maintain the perfect balance of energy – or equilibrium – that allows us to live and survive on Earth?

3rd rock from the Sun. Still too cold for life.

Average Surface Temperature
-18 C (~0 F)
If all of these types of energy from the Sun are always shining down on Earth, how does the Earth manage to maintain the perfect balance of energy – or equilibrium – that allows us to live and survive on Earth?

The planet Earth with its atmosphere – just the right balance for life to survive and thrive.

Average Surface Temperature
15 C (~59F)
The temperatures of Earth and all the planets are determined by their “Energy Budget.”
First, energy enters the Earth system from the Sun.

Earth’s Energy Budget
Some of that energy reflects off of clouds, dust, and other particles and never makes it to Earth’s surface. Most of that energy, however, does get to the surface, and once it gets there, the ground, trees, and everything else around us can absorb the energy.
However, there are some parts of Earth's surface that are highly reflective, like ice or snow, so in addition to absorbing energy, it also bounces off of those surfaces and heads right back out into space.
The world in reflected sunlight, May 25, 2001. Clouds, deserts and Arctic ice are bright. The south pole is in winter darkness with no sunlight to reflect.
All of that energy that is absorbed by the Earth doesn't just stay there and build up forever. The Earth system radiates that energy out towards space as heat. Cold objects emit less energy; warm objects emit more.
Most of the heat emitted from the surface is stopped on its way back out. Clouds and certain gases in the atmosphere absorb the energy, preventing it from leaving the system. Only a small window allows direct escape.
Energy emitted from those clouds and gases goes in all directions. Some comes back to further warm the Earth. This is the greenhouse effect.
Finally, the surface energy budget is balanced by thermals and evaporation.
Together all of these forms of incoming and outgoing energy have resulted in just the right living conditions for us on Earth.
The world in emitted heat, May 25, 2001. Deserts are hot; clouds and polar ice are cold. The south pole is in winter deep freeze.
Scientists use satellites, ground-based instruments, aircraft field campaigns, and computer models to determine the magnitude of each flux.

All values are fluxes in (W/m$^2$) and are average values based on 15 years of data.
Like your house, anything that increases or decreases the amount of incoming or outgoing energy would disturb Earth’s energy balance and would cause global temperatures to rise or fall.
Over the last decade, our best estimate is that there is a small positive imbalance in Earth’s energy budget.

Net absorbed by Earth System: 0.6 - 0.8

All values are fluxes in (W/m²) and are average values based on 15 years of data.
This is consistent with several other *lines of evidence* of a warming planet.

[Image: Ten Indicators of a Warming World]

https://www.globalchange.gov/browse/multimedia/ten-indicators-warming-world
The End
... for now
Details behind the story
Teaching Resources: The Electromagnetic Spectrum

https://mynasadata.larc.nasa.gov/basic-page/electromagnetic-spectrum-diagram
The Blackbody Spectrum

https://phet.colorado.edu/en/simulation/blackbody-spectrum
Equil Temp Calculation – An Equation!

Equil Temp = Temp_{star} * (1-albedo) \frac{1}{4} * \text{Square root}\left(\frac{\text{Radius}_{star}}{2 \times \text{Distance}}\right)

<table>
<thead>
<tr>
<th>Temp_{Sun} \sim 5778K</th>
<th>Radius_{Sun} \sim 695,500 \text{ km}</th>
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<tbody>
<tr>
<td>Albedo \sim 0.3</td>
<td>Distance \sim 149,600,000 \text{ km}</td>
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For Earth: Equil Temp \sim 254 \text{ K} = -18 \text{ Celsius}
Energy Budget Mini Lesson

CASE STUDY: Surface Effects on Energy Budget - Changes in Central Australia

Curriculum Unit Plan

Unit: Earth's Energy Budget
Greenhouse Effect

https://www.youtube.com/watch?v=b3NffWlfj24
Teaching Resources

http://science-edu.larc.nasa.gov/energy_budget/
# More Background Resources

https://science-edu.larc.nasa.gov/energy_budget/links.html

## Radiative Forcing
- Climate Forcings and Global Warming

## Radiation Budget
- Earth Observatory: Climate and Earth's Energy Budget
- MY NASA DATA Mini Lesson
- MY NASA DATA Seasonal Cycles
- NASA GISS-ICP: Global Equilibrium Energy Balance-Interactive Tracker Toy (GEEFIT)
- NASA GISS High School Unit Plan [PDF]
- PBS Learning Media: Earth's Delicate Energy Balance
- PBS Learning Media: Clouds and Earth's Energy Balance Audio Interview (Bruce Wielicki)
- UCARconnect: Tracking Earth's Energy Flow
- UCAR: Earth's Energy Balance Interactive
- Aqua CERES: Tracking Earth's Heat Balance
- How CO2 Warms The Climate - Ray Pierrehumbert
- eClips Real World Video
- Global Energy Balance Animated Diagram

## Atmospheric Layers
- Layers of the Earth's Atmosphere
- Atmosphere layers - Encyclopedia of Earth

## General Information
- NASA LARC Science Directorate Home Page
- NASA LARC CERES Home Page
Teaching Resources: Explore Data

Earth System Data Explorer