



Explaining Earth's Energy Budget: CERES-Based NASA K-12 Education and Public Outreach

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Resources for
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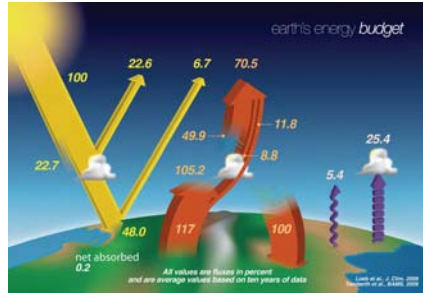
Introduction

Among atmospheric scientists, the importance of the Earth radiation budget concept is well understood. Papers have addressed the topic for over 100 years, and the large Clouds and the Earth's Radiant Energy System (CERES) science team (among others), with its multiple on-orbit instruments, is working hard to quantify the details of its various parts (i.e., Loeb et al., 2009).

In education, Earth's energy budget is a concept that generally appears in middle school and Earth science curricula, but its treatment in textbooks leaves much to be desired. Students and the public hold many misconceptions, and very few people have an appreciation for the importance of this energy balance to the conditions on Earth. More importantly, few have a correct mental model that allows them to make predictions and understand the effect of changes such as increasing greenhouse gas concentrations (Libarkin et al, 2013).

As an outreach element of the core CERES team at NASA Langley, a multi-disciplinary group of scientists, educators, graphic artists, writers, and web developers has been developing and refining graphics and resources to explain the Earth's Energy budget over the last few decades. Resources have developed through an iterative process involving ongoing use in front of a variety of audiences, including students and teachers from 3rd to 12th grade as well as public audiences.

Revised diagram



- Features:
- Based on Trenberth et al, 2009
- Updated with latest CERES values
- Careful color scheme
- Percent or W/m² version

Accompanying this diagram is a series of explanatory panels that can be used in a "create your own" classroom poster.

Accompanying Materials

The Story of Energy in the Earth System

The Sun is the source of energy for the Earth system. This energy reaches the Earth in the form of visible light, although it also includes some infrared energy. About 100 Watts of energy per square meter (W/m²) of the Earth's surface strikes the Earth every second. This energy is either reflected back to space or absorbed by the Earth's surface and atmosphere. About 70% of the energy is absorbed by the Earth's surface and atmosphere, and about 30% is reflected back to space. This energy is then re-emitted as infrared radiation back to space. This process is called the greenhouse effect.

Balancing the Energy Budget

For the Earth's energy budget to be balanced, the energy coming in from the Sun must be balanced by the energy going out to space. If the energy coming in is greater than the energy going out, the Earth will warm up. If the energy going out is greater than the energy coming in, the Earth will cool down. The Earth's energy budget is currently balanced, with about 100 W/m² of energy coming in and 100 W/m² of energy going out.

Energy Budget Since 1950

Since 1950, the Earth's energy budget has been changing. The amount of energy coming in from the Sun has increased slightly, and the amount of energy going out to space has decreased slightly. This has caused the Earth to warm up. The Earth's energy budget is now unbalanced, with about 100.5 W/m² of energy coming in and 99.5 W/m² of energy going out.

Seasonal Cycles in Net Radiative Flux

The Earth's energy budget varies throughout the year due to seasonal changes. The amount of energy coming in from the Sun is highest in the summer and lowest in the winter. The amount of energy going out to space is highest in the winter and lowest in the summer. This causes the Earth to warm up in the summer and cool down in the winter.

The Earth's Energy Budget

The Earth's energy budget is the balance between the energy coming in from the Sun and the energy going out to space. The Earth's energy budget is currently balanced, with about 100 W/m² of energy coming in and 100 W/m² of energy going out.

Energy Budget Detectives

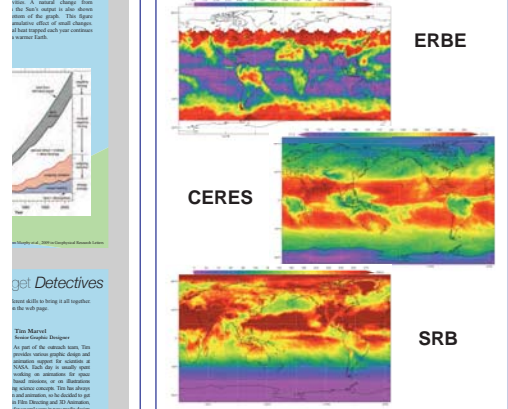
Energy Budget Detectives is a game that helps students understand the Earth's energy budget. The game is played by rolling dice and moving a token around a board. The board represents the Earth's energy budget, and the dice represent the different components of the budget.

Telling the Story

After years of experience using this diagram in talks for students, we also developed an Energy Budget "story" – a series of powerpoint slides that build up the diagram one piece at a time and allow students to "follow the energy" as the diagram comes together. We have found this to be an effective way to engage students with this rather complex diagram, and we continue to update and enhance the slide set based on questions and comments from our audiences.

Related Resources

Related resources for exploring the energy budget in the K-12 classroom are available as part of the MY NASA DATA project.
<http://mydasdata.larc.nasa.gov>



The LAS offers a simplified (and unified) interface that enables practical exploration of authentic NASA data in the K-12 classroom. Accompanying these data are a variety of explanatory materials (click on the Educators fold, then hover over the Radiation & Energy left navigation button to see what is available), as well as a number of lesson plans that use those data.

Website

http://science-edu.larc.nasa.gov/energy_budget/

References

Libarkin, J. C., H. Miller, S. R. Thomas, Scientists' internal models of the greenhouse effect, AGU Fall Meeting, San Francisco, CA, Dec. 2013.

Loeb, N. G., B. A. Wielicki, D. R. Doelling, G. L. Smith, D. Keyes, S. Kato, N. Manalo-Smith, and T. Wong, Toward optimal closure of the Earth's top-of-atmosphere radiation budget (2009), *J. Clim.*, **22**(3), 748-766, doi: 10.1175/2008jcli2637.1.

Trenberth, K. E., J. T. Fasullo, and J. Kiehl, Earth's Global Energy Budget, (2009) *Bull. Amer. Meteor. Soc.*, **90**(3), 311+, doi:10.1175/2008bams2634.1.

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