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

L H. Chambers[1], K. Bethea[2], M. T. Marvel[2], K. Ruhlman[2], J. LaPan[2], P. Lewis[2], J. Madigan[2], tra[2], and J. Taylor[2]

[1]NASA Langley Research Center, Hampton, VA [2]Science Systems and Applications, Inc. on, VA

National Aeronautics and Space Administration

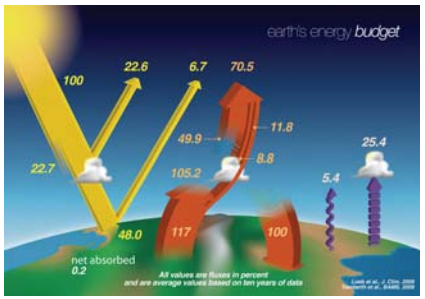
Introduction

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.

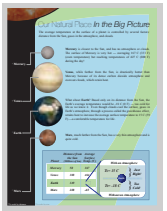
Revised diagram

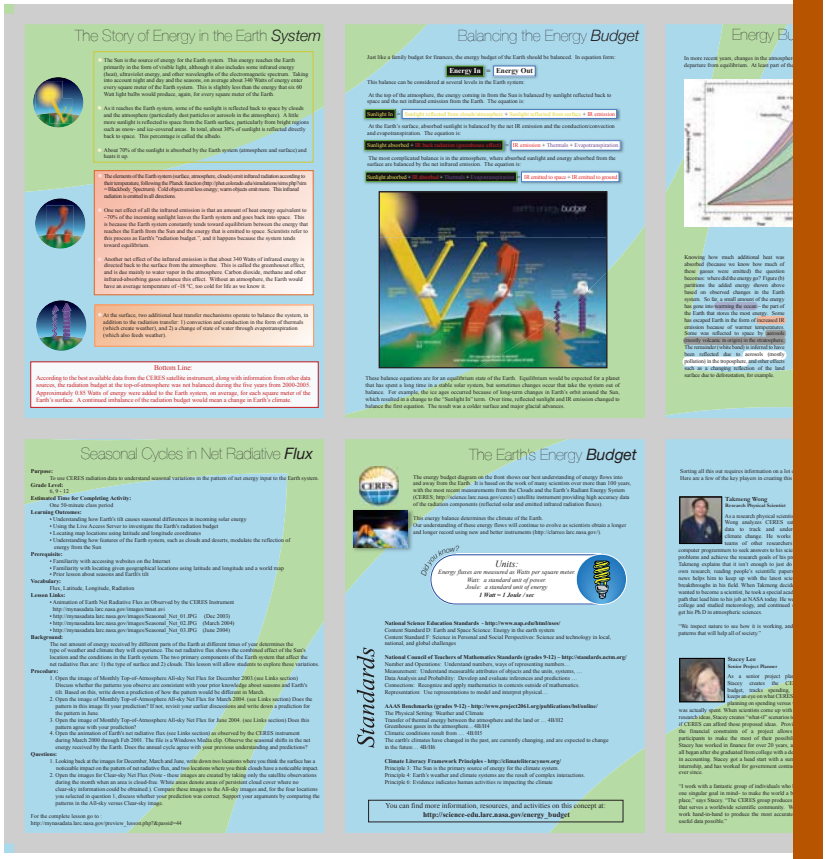


•Features:
- Based on Trenberth et al, 2009
- Updated with latest CERES values
- Careful color scheme
- Percent or W/m^2 version

Accompanying Materials

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



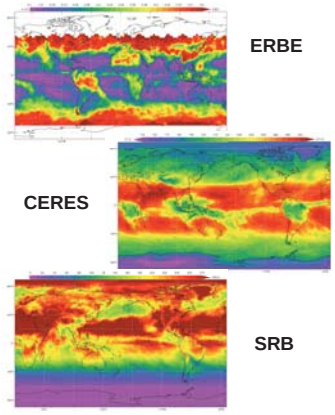


Telling the Story

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://mynasadata.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' nternal 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. F. 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.