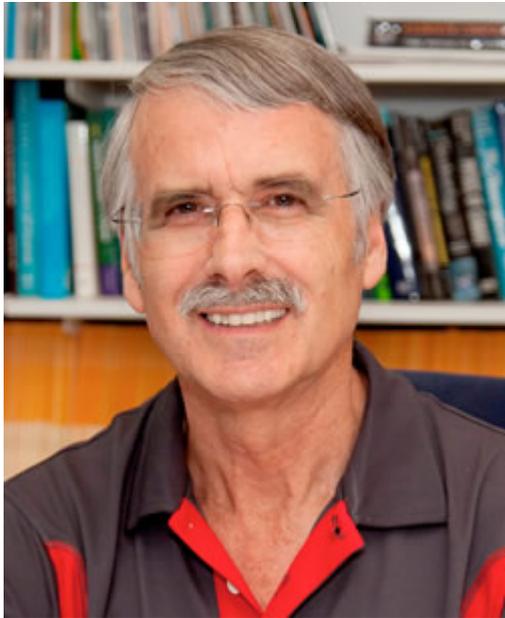


Energy and Climate - Dr Kevin E Trenberth



This is the first in a series of articles by renowned scientists. In it, Dr Kevin Trenberth of UCAR talks about energy and climate and addresses the intriguing issue of "missing energy"

[Dr Kevin E Trenberth Biography](#) ^[1]

[Youtube clip about missing energy](#) ^[2]

Climate change is very much involved with energy, most commonly in the form of heat but other forms of energy are also important. Radiation comes in from the sun (solar radiation at short wavelengths), and every body radiates according to its temperature (proportional to the fourth power of absolute temperature), so that on Earth we, and the surface and atmosphere radiate at infrared wavelengths. Weather and climate on Earth are determined by the amount and distribution of incoming radiation from the sun. For an equilibrium climate, global mean outgoing longwave radiation (OLR) necessarily balances the incoming absorbed solar radiation (ASR), but with redistributions of energy within the climate system to enable this to happen on a global basis. Incoming radiant energy may be scattered and reflected by clouds and aerosols (dust and pollution) or absorbed in the atmosphere. The transmitted radiation is then either absorbed or reflected at the Earth's surface. Radiant solar (shortwave) energy is transformed into sensible heat (related to temperature), latent energy (involving different water states), potential energy (involving gravity and altitude) and kinetic energy (involving motion) before being emitted as longwave infrared radiant energy. Energy may be stored, transported in various forms, and converted among the different types, giving rise to a rich variety of weather or turbulent phenomena in the atmosphere and ocean. Moreover the energy balance can be upset in various ways, changing the climate and associated weather.

The human influence on climate, arising mostly from the changing composition of the

atmosphere, affects energy flows. Increasing concentrations of carbon dioxide and other greenhouse gases have led to a post-2000 imbalance at the TOA of $0.9 \pm 0.5 \text{ W m}^{-2}$ (Trenberth et al. 2009) (Fig. 1), that produces “global warming”, or more correctly, an energy imbalance. Tracking how much extra energy has gone back to space and where this energy has accumulated is possible, with reasonable closure for 1993 to 2003. Over the past 50 years, the oceans have absorbed about 90% of the total heat added to the climate system while the rest goes to melting sea and land ice, and warming the land surface and atmosphere. Because carbon dioxide concentrations have further increased since 2003 the amount of heat subsequently being accumulated should be even greater. However, there was a slight decrease in solar insolation from 2000 until 2009 with the ebbing 11-year sunspot cycle; enough to offset 10 to 15% of the estimated net human induced warming.

The coldest month this century was January 2008 as a strong La Niña developed and influenced conditions throughout 2009. The resulting cold conditions around the world led to less longwave radiation back to space, and less convection and fewer clouds over the Pacific leading to increase absorbed solar radiation. Hence the net radiative imbalance at the top-of-atmosphere, as measured by CERES, showed a marked increase of order 1 W m^{-2} relative to surrounding years. These relative changes are well measured by CERES (Fig. 2). Hence the conundrum: more energy but colder temperatures. This gives rise to the concept of “missing energy” (Trenberth and Fasullo 2010). Where is the energy going? New estimates of ocean heat content show a growing large discrepancy between ocean heat content integrated for the upper 300 vs 700 vs total depth. The latter continues a fairly steady upward trend while the surface temperatures and upper ocean heat content undergo a hiatus in warming after about 2004. The role of the ocean in taking up energy well below the surface is emerging as a major issue in observations and modeling. Improved monitoring of TOA energy imbalance such as from a suite of small radiometers in space would prove exceedingly useful.

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Fig. 1. The global annual mean Earth's energy budget for 2000 to 2005 (W m^{-2}). The broad arrows indicate the schematic flow of energy in proportion to their importance. From Trenberth et al. (2009).

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Fig. 2. Recently updated net radiation ($RT = ASR - OLR$) from the TOA <http://ceres.larc.nasa.gov/products.php?product=EBAF> [3]. Also shown is the Niño 3.4 SST index (green) (left axis); values substantially above the zero line indicate El Niño conditions while La Niña conditions correspond to the low values. The decadal low pass filter is a 13 term filter making it similar to a 12-month running mean.

Source URL: <http://accsys.rmets.org/weather-and-climate/climate/energy-and-climate-dr-kevin-e-trenberth>

Links

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- [2] <http://www.youtube.com/watch?v=868nr1Pgxw0>
- [3] <http://ceres.larc.nasa.gov/products.php?product=EBAF>