Trenberth talks about energy flows and global warming

What The Science Says:
More up-to-date measurements show warming is consistent within observational uncertainties. Heat is continuing to build up in the subsurface ocean.

Climate Myth: Trenberth can't account for the lack of warming
in one e-mail, a top "warmist" researcher admits it's a "travesty" that "we can't account for the lack of warming at the moment." As it happens, the writer of that October 2009 e-mail—Kevin Trenberth, a lead author of the warmist bible, the 2007 Intergovernmental Panel on Climate Change (IPCC) report—told Congress two years ago that evidence for manmade warming is "unequivocal." He claimed "the planet is running a 'fever' and the prognosis is that it is apt to get much worse." But Trenberth's "lack of warming at the moment" has been going on at least a decade. (Michael Fumento)

Increased concentrations of greenhouse gases, from the burning of fossil fuels, slows the loss of heat from Earth's atmosphere to space. This creates an imbalance between incoming solar energy and outgoing heat. The Earth will continue to warm until the balance is restored.

Because this planetary heat imbalance is tiny compared to the energy coming in from the sun, and the heat being radiated back out to space, it is too small to be measured directly by satellites. Earlier attempts to quantify this planetary heat imbalance were made in Hansen (2005) and Trenberth (2009) using earlier climate model-based estimates. Hansen (2005) had this planetary imbalance at 0.85 (±0.15) watts per square meter, and Trenberth 0.9 (±0.5) W/m2, in the earlier part of this century.

An apparent mismatch between the modeled estimate and the heat that could be accounted for on Earth, led to well-known climate scientist, Kevin Trenberth to lament that it was a travesty. Trenberth was, of course, referring to the inadequate state of global observations, such as the sparsely sampled deep ocean among other things, but his comment was predictably distorted by misinformers and spawned a fake-skeptic climate myth of its own.

Loeb (2012) takes an updated look at the issue and finds that, using observations rather than modeled estimates, the Earth's energy imbalance is consistent with heat building up with the Earth system. They have this imbalance at 0.5 (±0.43) W/m2, much smaller than previous estimates, but the error margins are huge. Not unexpectedly the authors confirmed that heat is continuing to build up in the sub-surface ocean, which agrees with other recent sudies on ocean heat The persistent energy imbalance measured by this study is essentially future global warming, or "warming in the pipeline". It puts paid to wishful thinking-based claims that global warming has halted.

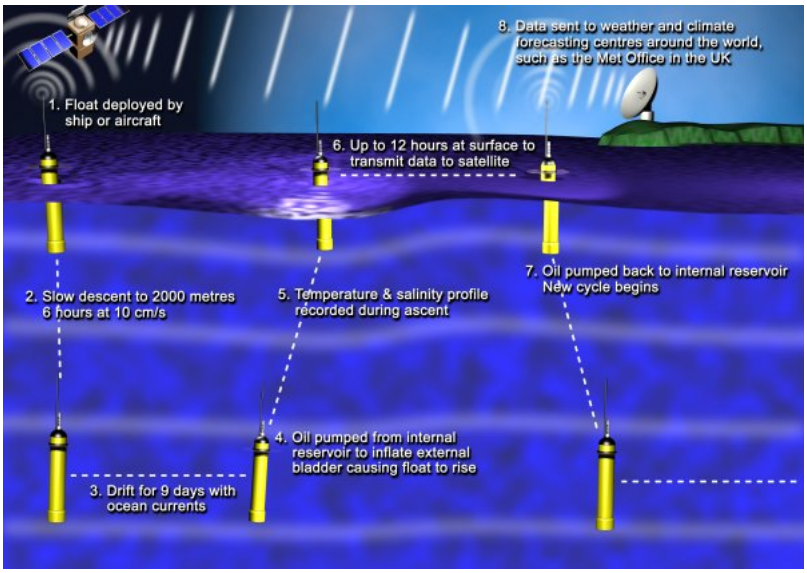

Figure 1: typical dive cycle of theARGO submersible float system - the most detailed set of ocean heat observations yet obtained. Image from NOAA.

An exercise in accounting

Earth's energy budget is determined by measuring how much energy comes into the Earth system from the sun, how much is lost to space as heat, and accounting for the remainder on Earth. Very little of this Earthbound energy goes into warming the atmosphere and land because they have a limited capacity to store heat. Likewise the energy required to melt ice is comparatively small.

The oceans, however, cover over 70% of the Earth's surface and, due to their enormous heat capacity compared to that of the atmosphere and land, store over 90% of the excess energy from global warming Quite obviously then, accurate measurements of ocean warming are crucial to balancing Earth's energy budget.

A little ocean heat content history

The ARGO float network consists of 3000 autonomous devices, distributed around the world's oceans, that sink down to depths of up to 2000 metres taking measurements of ocean temperature, as they ascend up through the water column. The system began to be rolled out in 2000, and by 2003 made up the majority of ocean heat measurements. The full roll-out of the 3000 floats was completed in late 2007. Although ARGO has not been without it's fair share of problems (as with any new technology), it represents a vast improvement over previous methods of sampling subsurface ocean temperature, such as the expendable bathythermographs (XBT's).

These are ship-launched devices that unfurl a trailing a copper wire as they descend down into the depths. It's through this wire which temperature information is transmitted back to a data collection system onboard the ship. Unlike the ARGO floats, XBT's don't have pressure sensors to measure depth, instead this is calculated by the rate at which the XBT falls. This calculation is carried out by software embedded in the XBT, and this timestamping of the temperature data is how depth is determined. Unfortunately this method has led to numerous problems in the ocean heat content record. See Abraham (2011).

From 1990 to 2002 these XBT's made up the bulk of ocean heat measurements, however because they were sparsely sampled in both time and space, numerous corrections and mapping strategies have had to be employed to remove errors and bias from the data set. From around 2002-2003, during the transition from XBT to ARGO, global ocean heating seems to decline. See figure 2.

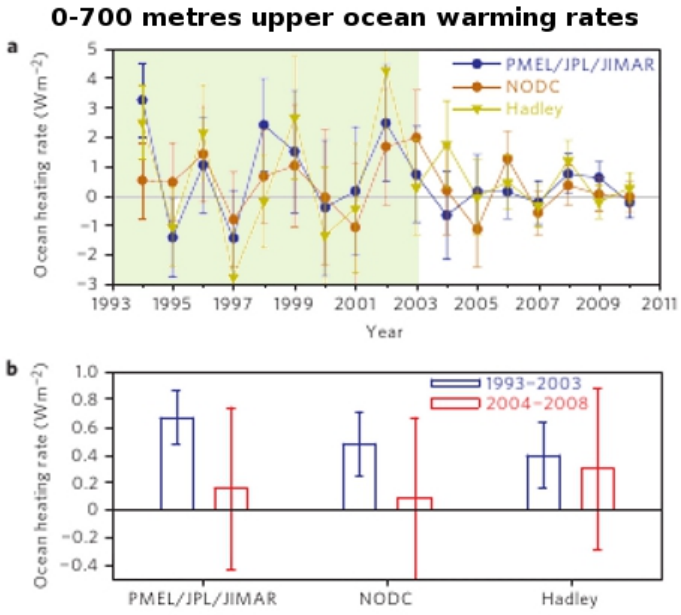

Figure 2: 0–700m upper-ocean warming rates. a, Annual global averaged upper-ocean warming rates computed from ?rst differences of the Paci?c Marine Environmental Laboratory/Jet Propulsion Laboratory/Joint Institute for Marine and Atmospheric Research (PMEL/JPL/JIMAR) 0–700m OHCA curve using data from Argo and theWorld Ocean Database 2009 the National Oceanic Data Center (NODC) 0–700m OHCA curve, and the Hadley Centre 0–700m OHCA curve. Uncertainties for all annual upper-ocean heating rates are given at one standard error and are derived from OHCA uncertainties. b, Means and uncertainties at the 90% con?dence level for 1993–2003 and 2004–2008. Adapted from Loeb (2012).

The light green area I've highlighted (in figure 2[a]) is the time period where the XBT were the dominant source of ocean heat content data. During 2003, when ARGO takes over as the major source of data, it's clear that the large year-to-year fluctuations abruptly shrink - an indication that the large variation was not real, but most likely a result of errors in the less accurate XBT-based system.

Also notable is the substantial variation in ocean heating rates between the three different ocean heat content data sets. In figure 2(b) are shown the ocean heating rates for the three data sets and their uncertainties. The period where ARGO data makes up the bulk of data (2004-2008 in red) has a greater uncertainty only because their period of observation is much shorter (5 years), versus 11 years for the interval where XBT data predominates (1993-2003 in blue). These uncertainties in ARGO will diminish as the length of the observational record grows, and indeed a decline in the scale of the annual fluctuation seems be occurring even within the 2004-2008 period.

The authors state:

> *"Although the different estimates of OHCA (ocean heat content anomaly) produce seemingly different estimates of interannual ocean heating rate variability, these differences are all within the range of observational uncertainty. The same conclusion is reached when ocean heating rates for 1993-2003 and 2004-2008 are compared (Fig. 2b). The decline after 2004 is therefore not statistically significant 3 , nor does it show up in a previous analysis of the Argo data"*

ENSO-induced changes in radiation flux at the top-of-the-atmosphere

As mentioned in the introduction, thesatellites which measure incoming and outgoing radiation at the top of Earth's atmosphere (TOA) cannot measure the small planetary energy imbalance brought about by global warming. It is over a hundred times smaller than the energy coming and going from the Earth. But, despite lacking absolute precision, the measuring instruments aboard the satellites are very stable. Therefore the large fluctuations at the top-of-the-atmsophere during ENSO (El Niño/La Niña) present another approach to tracking changes in Earth's energy imbalance.

El Niño and La Niña are not only intervals when heat within the system is distributed around the planet, but also periods which see a net loss of heat by the Earth (El Niño) and a net gain of heat (La Niña). Over the

long-term these intervals balance out to zero. This net loss/gain of planetary energy during El Niño/La Niña is ishown in figure 3 for the tropics (a) and the global situation (b).

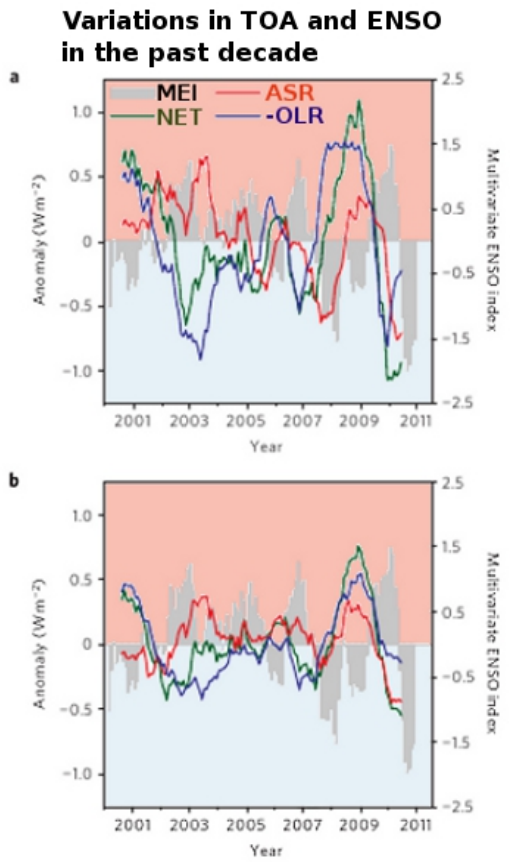

Figure 3: Variations in TOA radiation and ENSO during the past decade. a,b, Anomalies in net radiation (NET), absorbed solar radiation (ASR), the negative of outgoing longwave radiation (-OLR), and two-month averages of the Multivariate ENSO Index (MEI) for 30 S–30 N (a) and globally (b). Positive/negative anomalies correspond to a gain/loss of Earth energy. Positive and negative values of MEI correspond to El Niño (red shaded) and La Niña (blue shaded) conditions, respectively. TOA radiation anomalies are determined from monthly averages by removing the seasonal cycle then smoothing with a twelve-month running mean. Adapted from Loeb (2012).

Ocean Heat Content versus TOA flux observations

In order to compare these satellite-based observations with ocean heat content it is necessary to anchor the data to an absolute scale. Rather than use a model-based estimate, as did Hansen (2005) and Trenberth (2009), the authors achieve this by calculating it from observations of ocean heat content (down to 1800 metres) from the PMEL/JPL/JIMAR data sets over the period July 2005 to June 2010 - a time period dominated by the superior ARGO-based system.

By combining the ocean heating rates, TOA observations (figure 4) and other energy storage terms (land, atmosphere warming and ice melt), the authors calculated Earth's energy imbalance from January 2001-December 2010 to be 0.5 (±0.43) W/m2.

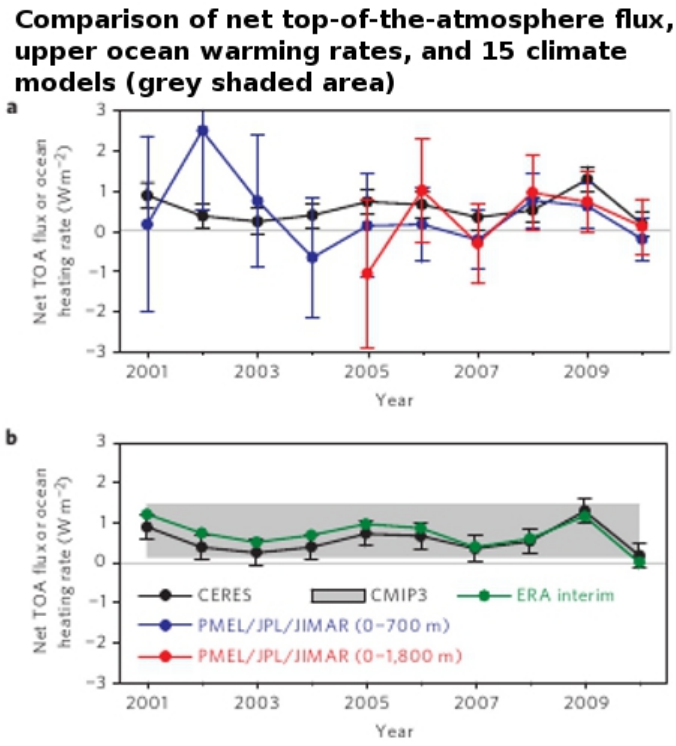

Figure 4 - Comparison of net TOA ?ux and upper-ocean heating rates. a, Global annual average (July to June) net TOA ?ux from CERES observations and 0–700 and 0–1,800m ocean heating rates from PMEL/JPL/JIMAR. Uncertainties for upper-ocean heating rates are given at one standard error derived from OHCA uncertainties. b, Net TOA ?ux from CERES, ERA-Interim reanalysis and the one standard deviation about the 2001–2010 average of 15 CMIP3 models (grey bar) are anchored to an estimate of Earth's heating rate for July 2005–June 2010. From Loeb (2012).

An obvious feature of the satellite TOA observations (figure 4) is that they do not show a sharp decline between 2002-2005 - the time of the transition from XBT to ARGO. Again this suggests that the scale of the 'slowdown' over that period is simply an artefact of the changeover from one system to the other, and may not be real. While the TOA observations show far less agreement with the NODC and Hadley Centre OHC data sets, after 2004 they demonstrate moderate agreement with PMEL/JPL/JIMAR data sets (as determined by statistical analysis).

The authors also note:

> "*Changes in CERES net TOA flux also show remarkable consistency with simulations from the European Centre for Medium-RangeWeather Forecasts (ECMWF) Interim Re-Analysis (ERA-Interim) (Fig. 4b, green line), which are completely independent of CERES*."

And:

> "*The rise and fall in CERES and ERA-Interim net radiation and upper-ocean heating rates after 2007 (Figs 2 and 4) is entirely consistent with variability linked to ENSO (Fig. 2) and shows no evidence of a discrepancy between TOA net radiation and energy accumulating in Earth's climate system*"

More warming in the pipeline

To sum up:

- Global warming is the result of a greenhouse gas-caused imbalance between incoming solar energy and heat that the Earth radiates away to space. Heat loss is reduced causing the planet to warm.
- Previous attempts to estimate this planetary imbalance relied on climate models rather than observations because sufficiently detailed observations were not available then.

- Loeb (2012) combined ocean heat content data, top-of-the-atmosphere satellite observations, heat absorbed by the land and atmosphere, and the energy required to melt ice. They found the global energy imbalance was 0.5 (±0.43) W/m2, smaller than previous estimates.
- The uncertainties are large due to the short length of robust observations, and because ARGO only samples down to 2000 metres - less than half the average depth of the global oceans.
- Although the deep ocean will have absorbed far less heat the the surface ocean it cannot be neglected in order to adequately balance the Earth's energy budget. See: SkS post: Ocean Heat Content And The Importance Of The Deep Ocean.
- The huge margin of uncertainty and the disparate heating rates between the three ocean heat data sets vindicate Kevin Trenberth's appeal that "we (the scientific community) must do better", but they will improve as the length of the observational record grows, and if proposed deep ocean observations, such as Deep Ninja, are put into place.
- And perhaps most crucially of all, **the persistent energy imbalance at the top-of-the-atmosphere (TOA) is representative of future global warming, or warming "in the pipeline." The Earth will continue to warm until the balance at TOA is restored**.

Advanced rebuttal written by dana1981

Update July 2015:

Here is a related lecture-video from Denial101x - Making Sense of Climate Science Denial

[*see video at **this link**.*]

Skeptical Science explains the science of global warming and examines climate misinformation through the lens of peer-reviewed research. The website won the Australian Museum 2011 Eureka Prize for the Advancement of Climate Change Knowledge. Members of the Skeptical Science team have authored peer-reviewed papers, a college textbook on climate change and the book Climate Change Denial: Heads in the Sand. Skeptical Science content has been used in university courses, textbooks, government reports on climate change, television documentaries and numerous books.