

## Ocean Warming said to Confirm Earth's Energy Imbalance

*Ocean's Inertia Delays Warming by Greenhouse Gases, but Makes it Hard to Reverse Course*

Measurements of ocean warming over the last 10 years now confirm that the Earth is out of energy balance, said James Hansen, director of NASA's Goddard Institute for Space Studies. The Institute's climate model predicted the same imbalance suggested by ocean observations. This energy imbalance can explain the warming observed in the 20<sup>th</sup> century, and also commits the planet to even more warming in the future resulting from past emissions of greenhouse gases. Hansen published the assertion on 28 April in [Science Express](#)<sup>1</sup> online.

"The primary symptom of Earth's thermal inertia," Hansen wrote, "is an imbalance between the energy absorbed and emitted by the planet." Hansen calculates that the surface of Earth is absorbing more energy than it is releasing back to space as heat. The extra energy is equivalent to one night-light shining on every square meter of the surface of Earth. The difference (in Watts) is the energy imbalance of the planet, which has been growing steadily since about 1960.

We describe in a [companion article](#) in this issue that the Ocean has tremendous thermal inertia – it takes centuries to warm up an ocean. That inertia causes climate to lag behind global changes that force warming or cooling; these changes are called "climate forcing agents," one example being an increase or decrease in carbon dioxide. A cool ocean delays the effect of climate warming agents until the ocean has fully warmed up. Climate forcing agents do their dirty work when they alter the balance between incoming solar energy and outgoing thermal energy on Earth. When incoming and outgoing energy is in balance, the planet neither warms nor cools. (See sidebar, "[Earth's Energy Balance](#).")

Hansen arrived at his conclusion by adding up the effects of many "climate forcing agents" on the energy balance in his climate model. Well-known warming agents include carbon dioxide (CO<sub>2</sub>), other greenhouse gases, ozone, and natural increases in the sun's output. Cooling agents include volcanic dust, aerosol particles, and land use change. As evidence that he estimated the energy balance correctly, he says his model has successfully simulated the 20<sup>th</sup> century global rise in land surface temperatures. Also "the imbalance (of energy) is confirmed by precise measurements of increasing ocean heat content over the past 10 years," according to Hansen.

The extra energy warms up the oceans very slowly, because of their thermal inertia. Two teams of scientists did measure the warming of the ocean, or at least its top layer of water. Sydney Levitus in 2000 [summarized 44 years of observations](#)<sup>2</sup> ending in 1998. Hansen's model predicts that the oceans gain heat at a rate only 9% greater than what Levitus observed. Last year [Willis and colleagues](#)<sup>3</sup> [published more complete data](#) on ocean warming in the 10 years ending in 2003. Hansen compared their rate of observed warming with the rate predicted by his model, and the two figures agree well.

In his model, not all the energy imbalance of Earth explained the observed warming of the ocean, but it did explain 80% of it. Most of the ocean observations are in the top 750 meters of water, where in fact most of the warming is. The remaining 20% of the energy probably goes into warming deeper layers of water, and warming the atmosphere.

The impact that climate forcing agents have had since industrialization began can be thought of as having two parts (see [sidebar](#)

for details). If all agents were acting from 1880 to 2003, the full effect would be an energy imbalance equivalent to two night-lights shining on each square meter of land and sea, more than twice as much as there really is now. Part of this “full effect” has already warmed the Earth about 0.6°C over the past century or two.

But the second part of the full effect is a delayed warming, which is now causing the ocean to warm and will cause future temperature rises. This part is the actual energy imbalance in 2003 that Hansen calculated and that agrees with ocean measurements. In Hansen’s view, the present imbalance leads to “unrealized warming” (in his words) or “committed warming” (see [companion article](#)), which is warming that must take place because of climate lag, but has not taken place yet.

The Institute’s model predicts that the present imbalance leads to a “committed” temperature rise of another 0.6°C in the future, in addition to warming that has already been observed. Even if no more greenhouse gases were emitted, this warming would occur. (See [companion article](#) for a different estimate.)

What are the implications of Hansen’s findings? He writes that “the present planetary energy imbalance is large by standards of Earth’s history.” If maintained for 10,000 years, it is enough to melt enough ice to raise sea level by 1000 meters, something that it is believed never to have happened. Hansen worries that the inertia of the oceans and the ice sheets, plus the amount of committed warming “in the pipeline,” may cause the Earth to reach a point where it is impossible to avoid a large change in sea level.

The other implication of “committed warming” is that it complicates the task of avoiding any chosen level of planetary warming. By the time actual warming is observed and its effects are agreed on, an equal amount of “committed warming” is “in

the pipeline” and will take place no matter what policies are enacted.

### Citations

1. “[Earth’s energy imbalance: confirmation and implications](#),” by James Hansen and 14 colleagues (2005). *Science*, v. 308, p. 1431-1434, 3 June 2005.
2. “[Warming of the world ocean](#),” by S. Levitus and 3 others (2000). *Science*, vol. 287, p. 2225.
3. “[Interannual variability in upper ocean heat content, temperature, and thermosteric expansion on global scales](#),” by J.K. Willis, D. Roemmich and B. Cornuelle (2004). *Journal of Geophysical Research*, vol. 109, C12036, doi:10.1029/2003JC002260.

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## Earth’s Energy Balance

The venerable old meteorologist Carl Gustav Rossby pointed out that the Earth does not have to be in energy balance, at least in the short term, as long as the Earth is warming or cooling. James Hansen calculates that the surface of Earth is absorbing more energy than it is releasing back to space as heat. The extra energy amounts to 0.85 Watts (or about as much as one night-light) for every square meter of land or sea, with an uncertainty of  $\pm 0.15$  Watts. This value represents the energy imbalance of the planet today.

The current imbalance is only a part of the full effect that greenhouse gases have had since industrialization began around 1750 or 1800. The full effect includes historic temperature changes resulting from past emissions of greenhouse gases (part 1), plus future temperature change also resulting from past emissions (part 2). Now “part 1” has caused temperatures to rise about 0.6°C in the past two centuries; an energy imbalance of one Watt per square meter is enough to have caused that. But Hansen’s model predicts that the full effect of climate warming and cooling agents over the last 200 years would have created an energy imbalance of 1.85 Watts for every square meter. The difference ( $1.85 - 1.00 = 0.85$  Watts per square meter) is the energy imbalance of “part 2,” associated with climate lag. As we said, it will cause warming in the future, but the warming has not taken place yet.