Measuring Global Temperatures: Satellites or Thermometers?

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The official global temperature numbers are in, and NOAA and NASA have decided that 2015 was the warmest year on record.

Based mostly upon surface thermometers, the official pronouncement ignores the other two primary ways of measuring global air temperatures, satellites and radiosondes (weather balloons).

The fact that those ignored temperature datasets suggest little or no warming for about 18 years now, it is worth outlining the primary differences between these three measurement systems.

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Three Ways to Measure Global Temperatures

The primary ways to monitor global average air temperatures are surface based thermometers (since the late 1800s), radiosondes (weather balloons, since about the 1950s), and satellites measuring microwave emissions (since 1979). Other technologies, such as GPS satellite based methods have limited record length and have not yet gained wide acceptance for accuracy.

While the thermometers measure near-surface temperature, the satellites and radiosondes measure the average temperature of a deep layer of the lower atmosphere. Based upon our understanding of how the atmosphere works, the deep layer temperatures are supposed to warm (and cool) somewhat more strongly than the surface temperatures. In other words, variations in global average temperature are expected to be magnified with height, say through the lowest 10 km of atmosphere. We indeed see this during warm El Nino years (like 2015) and cool La Nina years.

The satellite record is the shortest, and since most warming has occurred since the 1970s anyway we often talk about temperature trends since 1979 so that we can compare all three datasets over a common period.

Temperatures of the deep ocean, which I will not address in detail, have warmed by amounts so small — hundredths of a degree — that it is debatable whether they are accurate enough to be of much use. Sea surface temperatures, also indicating modest warming in recent decades, involve an entirely new set of problems, with rather sparse sampling by a mixture of bucket temperatures from many years ago, to newer ship engine intake temperatures, buoys, and since the early 1980s infrared satellite measurements.

How Much Warming?

Since 1979, it is generally accepted that the satellites and radiosondes measure 50% less of a warming trend than the surface thermometer data do, rather than 30-50% greater warming trend that theory predicts for warming aloft versus at the surface.

This is a substantial disagreement.

Why the Disagreement?

There are different possibilities for the disagreement:

1) Surface thermometer analyses are spuriously overestimating the true temperature trend
2) Satellites and radiosondes are spuriously underestimating the true temperature trend
3) All data are largely correct, and are telling us something new about how the climate system operates under long-term warming.

First let's look at the fundamental basis for each measurement.

All Temperature Measurements are "Indirect"

Roughly speaking, "temperature" is a measure of the kinetic energy of motion of molecules in air.

Unfortunately, we do not have an easy way to directly measure that kinetic energy of motion.

Instead, many years ago, mercury-in-glass or alcohol-in-glass thermometers were commonly used, where the thermal expansion of a column of liquid in response to temperature was estimated by eye. These measurements have now largely been

replaced with thermistors, which measure the resistance to the flow of electricity, which is also temperature-dependent.

Such measurements are just for the air immediately surrounding the thermometer, and as we all know, local sources of heat (a wall, pavement, air conditioning or heating equipment, etc.) can and do affect the measurements made by the thermometer. It has been demonstrated many times that urban locations have higher temperatures than rural locations, and such spurious heat influences are difficult to eliminate entirely, since we tend to place thermometers where people live.

Radiosondes also use a thermistor, which is usually checked against a separate thermometer just before weather balloon launch. As the weather balloon carries the thermistor up through the atmosphere, it is immune from ground-based sources of contamination, but it still has various errors due to sunlight heating and infrared cooling which are minimized through radiosonde enclosure design. Radiosondes are much fewer in number, generally making hundreds of point measurements around the world each day, rather than many thousands of measurements that thermometers make.

Satellite microwave radiometers are the fewest in number, only a dozen or so, but each one is transported by its own satellite to continuously measure virtually the entire earth each day. Each individual measurement represents the average temperature of a volume of the lower atmosphere about 50 km in diameter and about 10 km deep, which is about 25,000 cubic kilometers of air. About 20 of those measurements are made every second as the satellite travels and the instrument scans across the Earth.

The satellite measurement itself is “radiative”: the level of microwave emission by oxygen in the atmosphere is measured and compared to that from a warm calibration target on the satellite (whose temperature is monitored with several highly accurate platinum resistance thermometers), and a cold calibration view of the cosmic background radiation from space, assumed to be about 3 Kelvin (close to absolute zero temperature). A less sophisticated (infrared) radiation temperature measurement is made with the medical thermometer you place in your ear.

So, Which System is Better?

The satellites have the advantage of measuring virtually the whole Earth every day with the same instruments, which are then checked against each other. But since there are very small differences between the instruments, which can change slightly over time, adjustments must be made.

Thermometers have the advantage of being much greater in number, but with potentially large long-term spurious warming effects depending on how each

thermometer's local environment has changed with the addition of manmade objects and structures.

Virtually all thermometer measurements require adjustments of some sort, simply because with the exception of a few thermometer sites, there has not been a single, unaltered instrument measuring the same place for 30+ years without a change in its environment. When such rare thermometers were identified in a recent study of the U.S., it was found that by comparison the official U.S. warming trends were exaggerated by close to 60%. Thus, the current official NOAA adjustment procedures appear to force the good data to match the bad data, rather than the other way around. Whether such problem exist with other countries data remains to be seen.

Changes in radiosonde design and software have occurred over the years, making some adjustments necessary to the raw data.

For the satellites, orbital decay of the satellites requires an adjustment of the "lower tropospheric" (LT) temperatures, which is well understood and quite accurate, depending only upon geometry and the average rate of temperature decrease with altitude. But the orbital decay also causes the satellites to slowly drift in the time of day they observe. This "diurnal drift" adjustment is less certain. Significantly, very different procedures for this adjustment have led to almost identical results between the satellite datasets produced by UAH (The University of Alabama in Huntsville) and RSS (Remote Sensing Systems, Santa Rosa, California).

The fact that the satellites and radiosondes – two very different types of measurement system — tend to agree with each other gives us somewhat more confidence in their result that warming has been much less than predicted by climate models. But even the thermometers indicate less warming than the models, just with less of a discrepancy.

And this is probably the most important issue…that no matter which temperature monitoring method we use, the climate models that global warming policies are based upon have been, on average, warming faster than all of our temperature observation systems.

I do believe "global warming" has occurred, but (1) it is weaker than expected, based upon independent satellite and weather balloon measurements; (2) it has been overestimated with poorly adjusted surface-based thermometers; (3) it has a substantial natural component; and (4) it is likely to be more beneficial to life on Earth than harmful.

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