# Satellite temperature measurements

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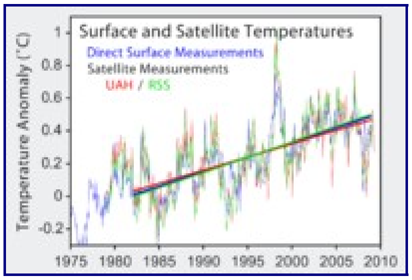
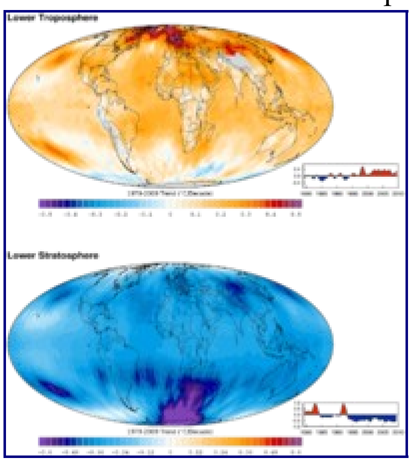



Comparison of ground based (blue) and satellite based (red: UAH; green: RSS) records of temperature variations since 1979. Trends plotted since January 1982.




Atmospheric temperature trends from 1979-2009 based on satellite measurements.

**Satellite temperature measurements** have been obtained from the troposphere since late 1978. By comparison, the usable balloon (radiosonde) record begins in 1958 but has less geographic coverage and is less uniform.

Satellites do not measure temperature. They measure radiances in various wavelength bands, which must then be mathematically inverted to obtain indirect inferences of temperature.[1][2] The resulting temperature profiles depend on details of the methods that are used to obtain temperatures from radiances. As a result, different groups that have analyzed the satellite data have obtained different temperature trends. Among these groups are Remote Sensing Systems (RSS) and the University of Alabama in Huntsville (UAH). Furthermore the satellite series is not fully homogeneous - it is constructed from a series of satellites with similar but not identical instrumentation. The sensors deteriorate over time, and corrections are necessary for satellite drift in orbit. Particularly large differences between reconstructed temperature series occur at the few times when there is little temporal overlap between successive satellites, making intercalibration difficult.

To compare to the trend from the surface temperature record (approximately +0.07 °C/decade over the past century and +0.17 °C/decade since 1979) it is most appropriate to derive trends for the part of the atmosphere nearest the surface, i.e., thelower troposphere. Doing this, through July 2010:

- RSS v3.2 finds a trend of +0.162 °C/decade.[3]

- UAH v5.3 finds a trend of +0.138°C/decade.[4]

An alternative adjustment introduced by Fu *et al.* (2004)[5] finds trends (1979-2001) of +0.19 °C/decade when applied to the RSS data set[6].

Using the T2 channel (which include significant contributions from the stratosphere, which has cooled), Mears et al. of Remote Sensing Systems (RSS) find (through January 2010) a trend of +0.090 °C/decade.[3] Spencer and Christy of the University of Alabama in Huntsville (UAH), find a smaller trend of +0.047 °C/decade.[7] A less regularly updated analysis is that of Vinnikov and Grody with +0.20°C per decade (1978–2005).[8] Another satellite temperature analysis is provided by NOAA/NESDIS STAR Center for Satellite Application and Research and use simultaneous nadir overpasses (SNO)[9] to remove satellite intercalibration biases yielding more accurate temperature trends. The SNO analysis finds a 1979-2009 trend of +0.131°C/decade for T2 channel.[10]

The satellite records have the advantage of global coverage, whereas the radiosonde record is longer. There have been complaints of data problems with both records, and difficulty reconciling climate model predictions with the observed data.

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# [edit] Reconciliation of satellites, radiosondes and climate models

Climate models predict that as the surface warms, so should the global troposphere. Globally, the troposphere should warm about 1.2 times more than the surface; in the tropics, the troposphere should warm about 1.5 times more than the surface. For some time the only available satellite record was the UAH version, which (with early versions of the processing algorithm) showed a global cooling trend for its first decade. Since then, a longer record and a number of corrections to the processing have revised this picture: the UAH dataset has shown an overall warming trend since 1998, though less than the RSS version. In 2001, an extensive comparison and discussion of trends from different data sources and periods was given in the Third Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) (section 2.2.4)[11].

A detailed analysis produced by dozens of scientists as part of the US Climate Change Science Program (CCSP) identified and corrected errors in a variety of temperature observations, including the satellite data.

The CCSP SAP 1.1 Executive Summary states:

> "Previously reported discrepancies between the amount of warming near the surface and higher in the atmosphere have been used to challenge the reliability of climate models and the reality of

> human induced global warming. Specifically, surface data showed substantial global-average warming, while early versions of satellite and radiosonde data showed little or no warming above the surface. This significant discrepancy no longer exists because errors in the satellite and radiosonde data have been identified and corrected. New data sets have also been developed that do not show such discrepancies."

The IPCC Fourth Assessment Report Summary for Policymakers states:

> "New analyses of balloon-borne and satellite measurements of lower- and mid-tropospheric temperature show warming rates that are similar to those of the surface temperature record and are consistent within their respective uncertainties, largely reconciling a discrepancy noted in the TAR."

However, as detailed in CCSP SAP 5.1 Understanding and Reconciling Differences, neither Regression models or other related techniques were reconcilable with observed data. The use of fingerprinting techniques on data yielded that "Volcanic and human-caused fingerprints were not consistently identifiable in observed patterns of lapse rate change." As such, issues with reconciling data and models remain.

A potentially serious inconsistency has been identified in the tropics, the area in which tropospheric amplification should be seen. Section 1.1 of the CCSP report says:

> "In the tropics, the agreement between models and observations depends on the time scale considered. For month-to-month and year-to-year variations, models and observations both show amplification (i.e., the month-to-month and year-to-year variations are larger aloft than at the surface). This is a consequence of relatively simple physics, the effects of the release of latent heat as air rises and condenses in clouds. The magnitude of this amplification is very similar in models and observations. On decadal and longer time scales, however, while almost all model simulations show greater warming aloft (reflecting the same physical processes that operate on the monthly and annual time scales), most observations show greater warming at the surface.
>
> "These results could arise either because “real world” amplification effects on short and long time scales are controlled by different physical mechanisms, and models fail to capture such behavior; or because non-climatic influences remaining in some or all of the observed tropospheric data sets lead to biased long-term trends; or a combination of these factors. The new evidence in this Report favors the second explanation."

The lower troposphere trend derived from UAH satellites (+0.128 °C/decade) is currently lower than both the GISS and Hadley Centre surface station network trends (+0.161 and +0.160 °C/decade respectively), while the RSS trend (+0.158 °C/decade) is similar. However, the expected trend in the lower troposphere, given the surface data, would be around 0.194 °C/decade, making the UAH and RSS trends 66% and 81% of the expected value respectively.

## [edit] The satellite temperature record

Since 1979, Microwave Sounding Units (MSUs) on NOAA polar orbiting satellites have measured the intensity of upwelling microwave radiation from atmospheric oxygen. The intensity is proportional to the temperature of broad vertical layers of the atmosphere, as demonstrated by theory and direct comparisons with atmospheric temperatures from radiosonde (balloon) profiles. Upwelling radiance is measured at different frequencies; these different frequency bands sample a different weighted range of the atmosphere.[12] Channel 2 is broadly representative of the troposphere, albeit with a significant overlap with the lower stratosphere (the weighting function has its maximum at 350 hPa and half-power at about 40 and 800 hPa). In an attempt to remove the stratospheric influence, Spencer and Christy developed the synthetic "2LT" product by subtracting signals at different view angles; this has a maximum at about 650 hPa. However this amplifies noise,[13] increases inter-satellite calibration biases and enhances surface contamination.[14] The 2LT product has gone through numerous versions as various corrections have been applied.

Records have been created by merging data from nine different MSUs, each with peculiarities (e.g., time drift of the spacecraft relative to the local solar time) that must be calculated and removed because they can have substantial impacts on the resulting trend.[15]

The process of constructing a temperature record from a radiance record is difficult. One widely reported satellite temperature record, developed by Roy Spencer and John Christy at the University of Alabama in Huntsville (UAH), is currently version 5.2 which corrects previous errors in their analysis for orbital drift and other factors. The record comes from a succession of different satellites and problems with inter-calibration between the satellites are important, especially NOAA-9, which accounts for most of the difference between the RSS and UAH analyses [16]. NOAA-11 played a significant role in a 2005 study by Mears *et al.* identifying an error in the diurnal correction that leads to the 40% jump in Spencer and Christy's trend from version 5.1 to 5.2.[17]

For some time, the UAH satellite data's chief significance was that they appeared to contradict a wide range of surface temperature data measurements and analyses showing warming in line with that estimated by climate models. In April 2002, for example, an analysis of the satellite temperature data showed warming of only 0.04 °C per decade, compared with surface measurements showing 0.17 ± 0.06 °C per decade. The correction of errors in the analysis of the satellite data, as noted above, have brought the two data sets more closely in line with each other.

Christy *et al.* (2007) find that the tropical temperature trends from radiosondes matches closest with his v5.2 UAH dataset.[18] Furthermore, they assert there is a growing discrepancy between RSS and sonde trends beginning in 1992, when the NOAA-12 satellite was launched[19]. This research found that the tropics were warming, from the balloon data, +0.09 (corrected to UAH) or +0.12 (corrected to RSS) or 0.05 K (from UAH MSU; ±0.07 K room for error) a decade.

# [edit] Discussion of the satellite temperature records

In the late 1990s the disagreement between the surface temperature record and the satellite records was a subject of research and debate. The lack of warming then seen in the records was noted.[20] A report by the National Research Council that reviewed upper air temperature trends stated:

> "Data collected by satellites and balloon-borne instruments since 1979 indicate little if any warming of the low- to mid-troposphere—the atmospheric layer extending up to about 5 miles from the Earth's surface. Climate models generally predict that temperatures should increase in the upper air as well as at the surface if increased concentrations of greenhouse gases are causing the warming."[21]

The same panel then concluded that

> "the warming trend in global-mean surface temperature observations during the past 20 years is undoubtedly real and is substantially greater than the average rate of warming during the twentieth century. The disparity between surface and upper air trends in no way invalidates the conclusion that surface temperature has been rising."[22][23]

As noted earlier, these temperature data, misinterpreted from the satellite data, are now known to have been too low.

An important critique of the satellite record is its shortness—adding a few years on to the record or picking a particular time frame can change the trends considerably. The problems with the length of the MSU record is shown by the table below, which shows the UAH TLT (lower tropospheric) global trend (°C/decade) beginning with Dec 1978 and ending with December of the year shown.

| Year | UAH Trend | RSS Trend |
|---|---|---|
| 1991 | 0.087 | |
| 1992 | 0.024 | |
| 1993 | -0.013 | |
| 1994 | -0.003 | |
| 1995 | 0.033 | |
| 1996 | 0.036 | |
| 1997 | 0.040 | |
| 1998 | 0.112 | |
| 1999 | 0.105 | |
| 2000 | 0.095 | |
| 2001 | 0.103 | |
| 2002 | 0.121 | |
| 2003 | 0.129 | |
| 2004 | 0.130 | |
| 2005 | 0.139 | |
| 2006 | 0.140 | |
| 2007 | 0.143 | |

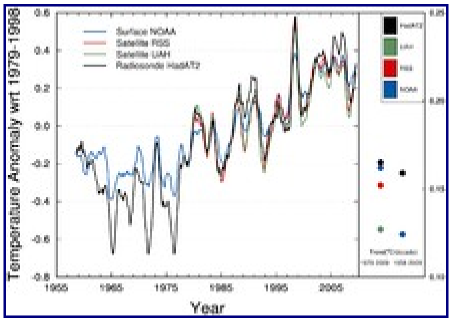
Likewise, even though they began with the same data, each of the major research groups has interpreted it with different results. Most notably, Mears et al. at RSS find 0.193 °C/decade for lower troposphere up to July 2005, compared to +0.123 °C/decade found by UAH for the same period.

There are ongoing efforts to resolve these differences. Some believe that much of the disparity may have been resolved by the three papers in Science, 11 August 2005, which pointed out errors in the UAH 5.1 record and the radiosonde record in the tropics.

## [edit] Satellite measurements of the stratospheric temperature

The satellites also measure the lower stratospheric temperature[*citation needed*] and show a decline in stratospheric temperatures, interspersed by warmings related to volcanic eruptions. Global Warming theory suggests that the stratosphere should cool while the troposphere warms [24] However, the lower stratospheric cooling is mainly caused by the effects of ozone depletion with a possible contribution from increased stratospheric water vapor and greenhouse gases increase [25] [26]. The long term cooling in the lower stratosphere occurred in two downward steps in temperature both after the transient warming related to explosive volcanic eruptions of El Chichón and Mount Pinatubo, this behavior of the global stratospheric temperature has been attributed to global ozone concentration variation in the two years following volcanic eruptions.[27] Since 1996 the trend is slightly positive[28] due to ozone recover juxtaposed to a cooling trend of 0.1K/decade that is consistent with the predicted impact of increased greenhouse gases.[27]

## [edit] Weather balloons (radiosondes)




1958-2009 radiosonde,satellite and surface temperature record.

The longest data sets of upper air temperature are derived from instruments carried aloft by balloons (radiosondes). The radiosonde data set becomes usably global in about 1958. Changes in balloon instrumentation and data processing over the years have been pervasive, however, resulting in discontinuities in these temperature records[29]. The Sherwood *et al.* (2005) study looked at solar heating issues and found a spurious trend of about -.16K per decade had been introduced into the record, asserting that this masked the true warming, particularly in the tropical regions.[30] This is enough to make the trend compatible with surface warming. Christy *et al.* (2007)[18] acknowledge the spurious trends in the radiosondes and assert that "[w]hen the largest discontinuities in the sondes are detected and removed," a cooler heating trend (in line with their UAH v5.2 dataset) than the one previously held is found.[19]

The radiosondes and the MSU were designed to detect short term changes in temperatures and not long term trends so it would be inappropriate to criticize them for being poor for long term trend detection. Other problems with the radiosondes in addition to the recently discovered solar heating issue could remain in the data.

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