Global Temperature Report

1978 - 2003

Earth System Science Center
The University of Alabama in Huntsville

Dr. John Christy & Dr. Roy Spencer

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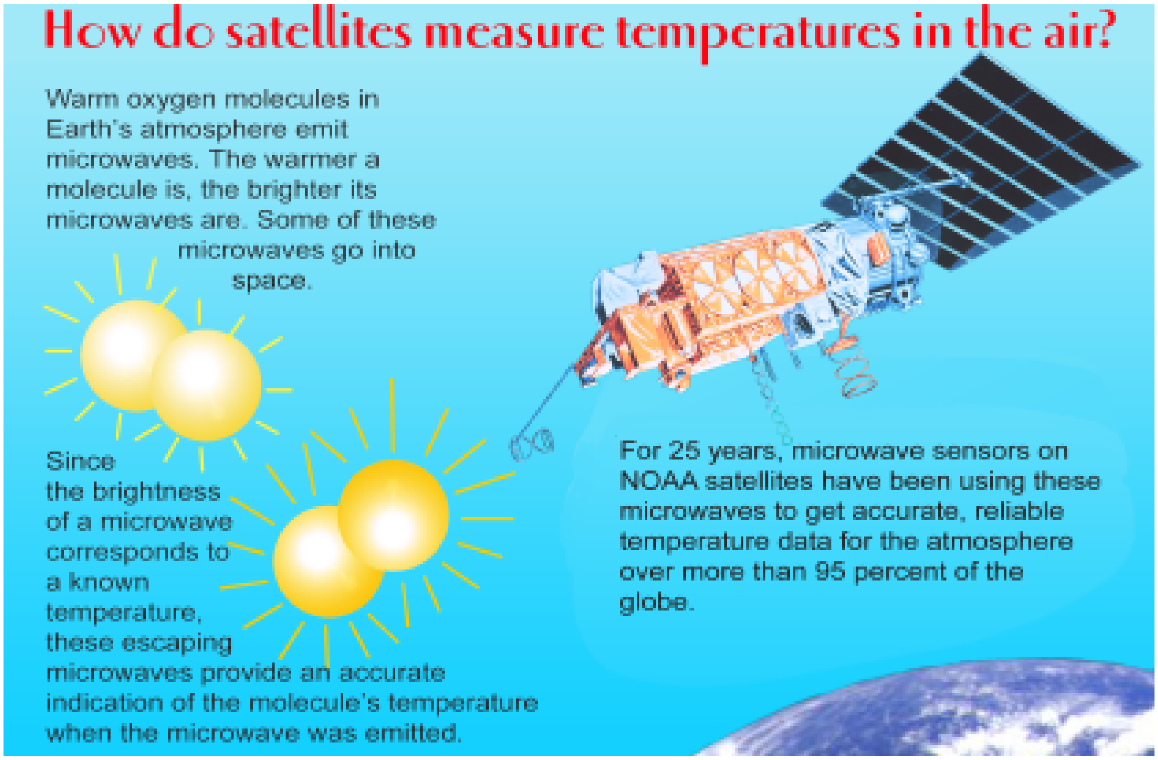


How do satellites measure temperatures in the air?

Warm oxygen molecules in Earth's atmosphere emit microwaves. The warmer a molecule is, the brighter its microwaves are. Some of these microwaves go into space.

Since the brightness of a microwave corresponds to a known temperature, these escaping microwaves provide an accurate indication of the molecule's temperature when the microwave was emitted.

For 25 years, microwave sensors on NOAA satellites have been using these microwaves to get accurate, reliable temperature data for the atmosphere over more than 95 percent of the globe.

25 years of taking Earth's temperature

In early November 1978 a microwave sensor aboard the National Oceanic and Atmospheric Administration's TIROS polar-orbiting satellite started scanning the Earth's atmosphere.

It was looking at the intensity of microwaves emitted by oxygen molecules. Since the intensity of those microwaves relates directly to the temperature of the oxygen molecules, they provide an accurate "thermometer" for temperatures in the atmosphere.

The National Weather Service hoped to use that nearly global temperature data to improve its weather forecasts.

Unfortunately, the computer forecasting models were designed to use precise temperature data from 14 designated altitudes. That data is collected by "radiosondes," instruments carried aloft by helium balloons.

The microwave sensors "see" huge volumes of atmosphere — about 50,000 cubic kilometers for each reading.

The data didn't fit the forecast models and, as day-to-day tools for forecasters, the microwave sensors weren't very useful. (The data has since been used to substantially improve the accuracy of weather forecasting models.)

The data the sensors collected, however, were dutifully recorded and stored. In a decade they created a tremendous backlog of data, including more than 500 million temperature readings.

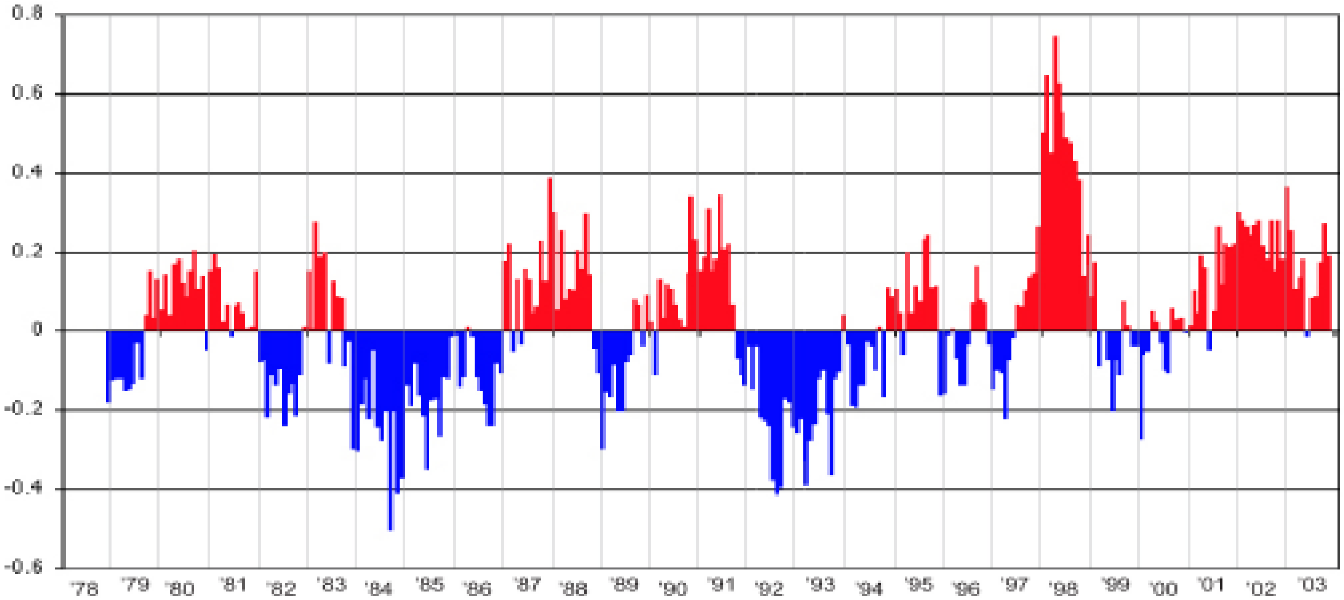
In 1989 Dr. Roy Spencer, at that time a space scientist at NASA's Marshall Space Flight Center, proposed using the microwave data to look at global atmospheric temperatures.

An expert in microwave sensors, Spencer teamed with Dr. John Christy from The University of Alabama in Huntsville (UAH) to analyze the data.

They concentrated on data from two altitude ranges: The lower troposphere, from sea level to about six miles high, and the lower stratosphere above 10 miles. In March 1990 they published their findings in *Science*: Although global climate models predicted global warming due to increased CO_2 in the atmosphere should show up first and strongest in the troposphere, the first ten years of satellite data showed no sign of warming in that layer of the atmosphere.

Now, with 25 years of data in hand, that result has changed.

Spencer, R.W., and J.R. Christy, "Precise monitoring of global temperature trends from satellites." Science, ***247****, 1558-1562, 1990.*



Monthly global temperature deviations from seasonal norms, in Celsius

The atmosphere is warming

Since Nov. 16, 1978, the global lower troposphere has warmed almost 0.2 Celsius (about 0.34° Fahrenheit), or global warming at the rate of approximately 0.76 C (about 1.38° Fahrenheit) per century.

Most of the warming that accounts for that trend, however, has happened since January 1998 in the northernmost third of the globe. (*Please see map on page 9.*)

There has been no net warming in the tropics over the past 25 years, while there is very slight warming in the southernmost third of the globe.

While the 25-year warming is within the range of natural climate variation, some of the warming is consistent with human effects — especially warming in the coldest air over the Northern Hemisphere, according to Christy. "That cold air has very little water vapor in it, so if you add another greenhouse gas you have an opportunity to trap more heat.

"When you go to the tropics, where there's lots of water vapor, the extra carbon dioxide doesn't have as much effect. As a greenhouse gas, carbon dioxide's greatest effect is in the driest, coldest places."

Global composite temperatures were driven by major climate events, including volcanic eruptions, seven El Niño Pacific Ocean warming events and four La Niña Pacific Ocean cooling events.

Compared to seasonal norms, the hottest day in the past 25 years was April 6, 1998, when the global composite temperature climbed to 0.92 C (1.66° F) above normal.

April 1998 was also the warmest month, with an average global composite temperature that was 0.75 C (1.35° F) warmer than seasonal norms.

The 1997-1998 "El Niño of the century" made 1998 the hottest calendar year during the 25-year record, with an annual average temperature that was 0.47 C (0.85° F) warmer than normal.

The hottest 12-month period, however, was from November 1997 through October 1998, with an average global composite temperature that was 0.473 C warmer than normal.

By contrast, the coolest 12-month period was from June 1992 through May 1993, when the eruption of the Mount Pinatubo volcano drove the average global com-posite temperature 0.28 C (0.5° F) below normal. The volcano erupted at the beginning of an El Niño warming event, which helped to offset the volcano's cooling effects.

The coolest calendar year was 1985, at 0.25 C (0.45° F) below normal. The coolest month was September 1984, at 0.50 C (0.9° F) below normal.

The coldest day was September 19, 1984, when the global composite temperature dropped 0.67 C (1.21° F) below seasonal norms.

Confirming the temperature data

The UAH dataset is the only satellite-based temperature dataset that has multiple, independent studies verifying its accuracy.

“Ours is the only dataset that has been compared to non-satellite data,” said Christy. “This gives us confidence in its results. Several different radiosonde-based products have been compared to the satellite data and the results of those studies have been published.”

In 1992, Christy and Spencer published a study in which they compared the satellite data to a set of U.S. radiosondes.

In 1997, the Hadley Center of the United Kingdom’s Meteorology Office did an analysis using data from 400 radiosonde sites around the world. There was extremely close agreement between that radiosonde data and the UAH dataset.

Additional studies comparing the satellite and radiosonde data have appeared in reports published by the IPCC and the National Research Council.

The most recent comparison was published in 2003 in the *Journal of Atmospheric and Oceanic Technology*. In each case, the satellite data and the radiosonde data show a high level of agreement.

Each microwave sounding unit is also calibrated before launch, using heating elements warmed to precise temperatures.

In space, each microwave sounding unit self-calibrates every cycle. It views a warm target whose temperature is precisely monitored and then deep space, which has a temperature near absolute zero. Then it takes measurements of the Earth’s atmosphere across a swath below the spacecraft.

Christy, J.R., R.W. Spencer, W.B. Norris, W.D. Braswell and D.E. Parker, “Error estimates of Version 5.0 of MSU/AMSU bulk atmospheric temperatures.” *Journal of Atmospheric and Oceanic Technology*, 2003, **20**, 613-629.

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Hurrell, J., S.J. Brown, K.E. Trenberth and J.R. Christy, “Comparison of tropospheric temperatures from radiosondes and satellites: 1979-1998.” *Bulletin of the American Meteorological Society*, 2000, 81, 2165-2177.

Christy, J.R., R.W. Spencer, and D. Braswell, “How accurate are satellite ‘thermometers’?” *Nature*, 1997, 389, 342-3.

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Finding and correcting errors

As the satellite data become longer in extent, various issues became apparent that needed to be dealt with to ensure the data's long-term accuracy.

Spencer and Christy discovered three of the four major problems that have been identified — orbital drift, instrument body warming and inter-instrument calibration — found solutions to those problems and published their results in peer-reviewed journals.

The fourth problem, orbital decay, was identified by Dr. Frank Wentz, et al., and a correction technique similar to one that he and his colleagues developed has been applied to the UAH dataset.

Orbital drift (or precession)

The orbital drift of NOAA's TIROS satellites causes two problems with the temperature data.

A spacecraft launched to observe at 2 p.m. and 2 a.m. local time will drift to later local times through its operational lifetime, say to 5 p.m. and 5 a.m.

Because a typical location on Earth naturally cools between 2 (p.m. or a.m.) and 5 (p.m. or a.m.), a satellite observing this cooling over its lifetime would record a spurious long-term cooling trend.

To remove this diurnal drift effect UAH uses measurements taken by the satellites. Every 25 seconds the scanner sweeps west to east over a 2,000 km strip, observing the earth at different local times. Using all of these measurements we are able to calculate an atmospheric temperature value vs. local time to use as a correction (see Christy et al. 2003 for details.)

By using these observations the subtle features of the diurnal cycle, such as stratospheric tides and latent heating cycles over oceans, are accounted for. Separate adjustment values are found for land vs. ocean, each month of the year and each latitude band. This conservative approach is empirical in nature, relying on observed data.

Instrument body warming

Orbital drift also changes the angle at which sunlight strikes the instrument during its pass over the daylight side of the planet. Parts of the instrument differentially heat or cool due to changing shadows as the satellite's orbit drifts. The value of the measured atmospheric temperature tends to show a small spurious heating or cooling proportional to the temperature of the instrument components.

UAH discovered this effect (Christy et al. 2000) and developed a technique to remove it. A coefficient is calculated for each satellite which — when multiplied by the change in instrument temperature — determines the erroneous atmospheric temperature effect. This error can then be removed. UAH does this only when there is an obvious correlation between instrument temperatures and atmospheric temperature errors.

UAH also smoothes the data before calculating these coefficients. This produces higher correlations between instrument temperature and the component of erroneous atmospheric temperature. This gives higher confidence in the accuracy of the correction.

Orbital decay

Satellites lose altitude over time as their orbits decay. Wentz, et al, found that this loss of altitude changes the "footprint" seen by the microwave sound unit, introducing a false cooling signal into the data.

UAH developed a method for removing this false signal, which has been applied to the dataset.

Inter-instrument calibration

If a new satellite with a new microwave sensor is launched while one or more old TIROS satellites are still in orbit, that overlap gives Christy and Spencer an opportunity to check one instrument against the other.

This provides an additional layer of verification, while also helping identify potential instrument problems.

Spencer and Christy use daily temperature readings from each satellite, corrected for known false signal effects, to intercalibrate the satellite instruments and produce a more homogeneous and accurate long-term temperature record.

Conflicting climate data

A common feature of climate model forecasts is that as CO_2 increases, the global surface temperature should rise along with an even more rapid warming in the troposphere — the atmosphere up to about 30,000 feet. This additional atmospheric warming would further promote warming at the surface — if models are correct.

Surface temperature records indicate a long-term atmospheric warming trend of about 3° Fahrenheit per century.

Other research, however, finds the signs of major global warming more difficult to identify.

Long-term studies of El Niño Pacific Ocean warming events show that they are no more frequent now than in the past millenia.(1)(2)

Recent studies show sea conditions in the Arctic today are similar to conditions in the late 19th and early 20th centuries, while average Arctic temperatures are rising almost to their levels of the 1930s.(3)(4)(5)

Climate studies in the Antarctic report long-term cooling trends on scales ranging from 30 to more than 1,000 years, and that the ice cap there is growing.(6)(7)(8)

Studies of severe weather events in North America found no evidence that extreme weather events, including tornadoes, are more common or more violent now than they were in the late 1800s.(9)(10)

An analysis of hurricane and tropical cyclone data found those storms are not becoming either more frequent or more violent.(11)(12)

A study of mean global sea level found the approximately 3 mm/y rise of the past 150 years has not accelerated during the 20th century.(13)

And a recent Harvard-Smithsonian study(14) of more than 240 paleoclimate research papers published in the past four decades concluded that the 20th century was neither the warmest century nor the century with the most extreme weather of the past 1,000 years for specific regions.

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(2) Reidinger, M.A., M. Steinitz-Kannan, W.M. Last and M. Brenner, “A ~6100 ^{14}C yr record of El Niño activity from the Galapagos Islands.” *Journal of Paleolimnology*, 2002. 27: 1-7.

(3) Przbylak, R., “Temporal and spatial variation of surface air temperature over the period of instrumental observations in the Arctic.” *International Journal of Climatology*, 2000. 20: 587-614.

(4) Holloway, G., and T. Sou, “Has Arctic Sea Ice Rapidly Thinned?” *Journal of Climate*, 2002. 15: 1691-1701.

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(11) Landsea C.N., R.A. Pielke, A.M. Mestas-Nuñez and J.A. Knaff, “Atlantic basin hurricanes: Indices of climatic changes.” Climatic Change, 1999. 42: 89-129.

(12) Raghavan, S., and S. Rajesh, “Trends in tropical cyclone impact: A study in Andhra Pradesh, India.” Bulletin of the American Meteorological Society, 2003. 84: 635-644.

(13) Douglas, B.C., and W.R. Peltier, “The puzzle of global sea-level rise.” Physics Today, 2002. 55:35-40.

(14) Soon, W. and S. Baliunas,“Proxy climatic and environmental changes of the past 1000 years.” *Climate Research*, 2003, 23: 89-110.

The ongoing climate conundrum

One of the hottest controversies in climate science is the apparent disagreement between temperature data collected by thermometers at the surface and the satellite dataset.

“Global” surface thermometer networks show a warming trend of approximately 1.7 degrees Celsius per century — about 3° Fahrenheit. The satellite data show a warming trend that is less than half that much, only 0.76 C or about 1.38° F per century.

Why do the two datasets disagree and which is the more accurate representation of the climate, especially since general circulation climate models used to predict global warming agree that anthropogenic warming should be seen first and strongest not at the surface but in the lower troposphere?

A recent analysis of the surface and satellite datasets hints that the apparent disagreement might have as much to do with coverage as with differing trends at different altitudes.

“In areas where you have high resolution, well-maintained scientific collection of temperature data, the satellites and the surface data show a high degree of agreement,” said Christy. “Over North America, Europe, Russia, China and Australia, the agreement is basically one-to-one.”

The satellite dataset provides tropospheric temperature information for more than 95 percent of the globe, excluding only the small portions of the poles not seen by the satellite instruments and those places where the troposphere is full of mountains or high plateaus.

The satellite-based microwave sounding units provide temperature data for many regions for which reliable climate data are not otherwise available, including many remote desert, jungle, ocean or mountain areas.

By comparison, surface temperature datasets have reliable data for much less of the globe. One widely cited dataset achieves significant global coverage only when each thermometer is assumed to provide temperature data within a 1,200 kilometer radius — equivalent to using a thermometer in Topeka, Kansas, to record temperatures from Brownsville, Texas, to Grand Forks, North Dakota.

The greatest disagreement between the surface and satellite datasets is in the tropics, which includes regions where weather stations are sparse (including central Africa and South America), and the three-fourths of the tropics that are covered by oceans, where proxy information such as sea surface temperatures is used in lieu of actual atmospheric temperature data.

The value of sea surface temperatures as a proxy for air temperatures is in question after recent research found that sea surface temperatures and air temperatures as little as ten feet above the surface do not move in precise accord with one another.

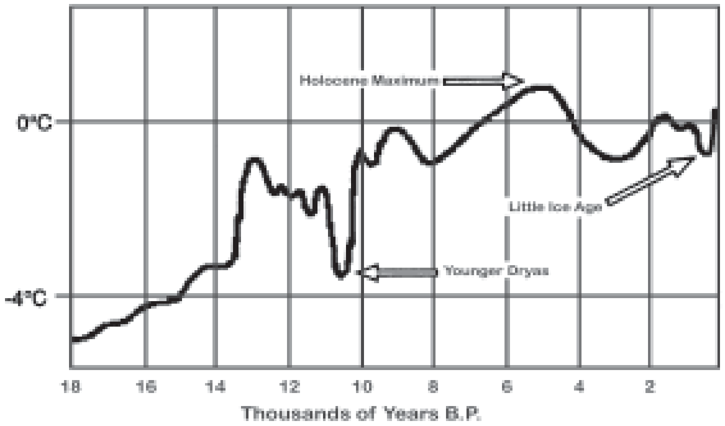
There are other questions about the sea surface data. For decades, the majority of “sea surface” temperatures recorded were actually the temperatures of ocean water pumped onboard seagoing ships from as much as 30 feet below the surface.

In recent years much of the sea surface temperature data gathering has been done by a network of scientific buoys, which record temperatures at several depths, including the actual sea surface.

In most of the major surface temperature records, however, those two datasets were merged with little or no adjustment for the change in collection method or depth.

The spurious effects of these inconsistencies are thought to be small. The best conclusion may be that the surface and tropospheric temperatures are just going in slightly different directions.

Earth's climate is constantly changing



*Estimates of global temperature variations over the past 18,000 years determined from proxy information. (*Earthquest, *Office of Interdisciplinary Earth Studies, Spring 1991, Vo. 5, p. 1.)*

There is no scientific evidence to support the belief that Earth's climate is stable and will not change if human activity does not intervene.

To the contrary, paleoclimate data indicates that Earth's climate is constantly changing and has never been stable.

Glaciers and polar ice caps have been melting for much of the past 20,000 years as global average temperatures climbed approximately 8 C (more than 14° Fahrenheit). There is no scientific reason to believe this process will end in the next few decades.

Because glaciers and ice caps were melting, sea surface levels around the world rose at the rate of about one meter per century for about the first 6,000 of those 20,000 years.

Sea level changes at those rates are not expected in the near term. (Sea levels rose about six inches in the past century.)

"To match the last warm period of about 130,000 years ago, the sea needs to rise about six meters — almost 20 more feet," said Christy. "Until the next ice age, we should expect more land ice to melt and sea levels to rise."

Paleoclimate data indicates that the climate is capable of significant changes for reasons that are not understood.

If Earth's climate follows the chaotic pattern of previous eons, our descendents will see climate changes that bring increased rain to some areas and decades-long droughts to others; cooling in some regions and warming in others.

The fossil and geological records indicate that some of these changes will happen rapidly, with major regional climate shifts occuring in time scales as brief as years or decades.

The 'Little Ice Age' that marked the end of the Medieval Warm Period and for several centuries brought a return of ice and snow to much of the world has ended.

Evidence from several sources indicates that Earth's rising temperatures are approaching the high levels of the Holocene Maximum more than 5,000 years ago.

While the approximately 0.14° (Fahrenheit) per decade of global warming seen in the satellite data is minor compared to the scale of some past climate shifts, it reminds us that the natural processes of climate change have not stopped.

Looking at the history of Earth's climate, the preponderance of scientific evidence indicates that the climate will almost certainly change in the future.

The current level of knowledge about the climate doesn't provide the tools needed to predict when rapid natural climate changes will occur and what forms it might take. This makes it impossible to say with high confidence how much human factors might influence climate change.

Although both the forces that drive natural climate change and the events that trigger major climate events are too poorly understood to allow confident climate forecasts, the atmospheric science community is making major strides.

In the future, it may be possible for scientists to improve the reliability of climate predictions while at the same time accurately and comprehensively monitoring Earth's climate, and providing information about climate change as it occurs.

Climate and environmental priorities

If artificially-enhanced global warming at potentially damaging levels isn't happening, what might that mean in terms of environmental and conservation priorities?

At hearings before Congressional committees and in other settings, we have been asked the hypothetical question: "If you were in charge, what would you do about climate change and the environment?"

The first thing is to do no harm. With the threat of catastrophic climate change, many proposals have been put forward to limit energy use.

A fundamental point that needs to be understood is that if any of these proposals (including the Kyoto protocol) are implemented, they will have an effect on the climate so small that it cannot be detected. None of these proposals will change what the climate is doing enough to notice.

Those are good reasons not to artificially force energy prices up. While raising energy costs might damage the economy, it would disproportionately hurt the poor, especially those people living on the world's social and economic fringes.

While no direct evidence of ecological damage from carbon dioxide has been found, that is no excuse for reducing environmental protection. We shouldn't undo the good things that have been done to clean the air and water. More should be done, especially in developing countries.

Beyond quality of life issues, human life itself is significantly more threatened by polluted water, polluted air, habitat destruction, unbridled population growth and a host of related ecological problems than it is by global climate change on the scales that we have seen in the past 25 years.

Millions of children around the world die every year due to water borne diseases. Tens of millions of people are forced to breathe air that is blackened and made toxic by fumes from leaded gasoline, industrial pollution and cooking fires.

Women and girls in some developing countries are forced to walk miles each day from their villages to the receding edges of the forests to harvest green wood and other low-energy biomass for the fires they use to cook their meals and heat their homes.

A recent U.N. report estimated that 1.6 million people — most of them women and children — die each year due to indoor pollution from cooking fires.

While the extent of human impacts on global climate change remains uncertain, recent research by our colleagues at UAH confirms that deforestation and land conversion are changing regional weather patterns and the local climate over some parts of the world.

We should also do what the U.S. does best: We should encourage and support the scientists and engineers who will develop new sources of low-cost energy. Just as transportation was "de-horsified" in the last century, we believe energy in the 21st century will continue to be de-carbonized.

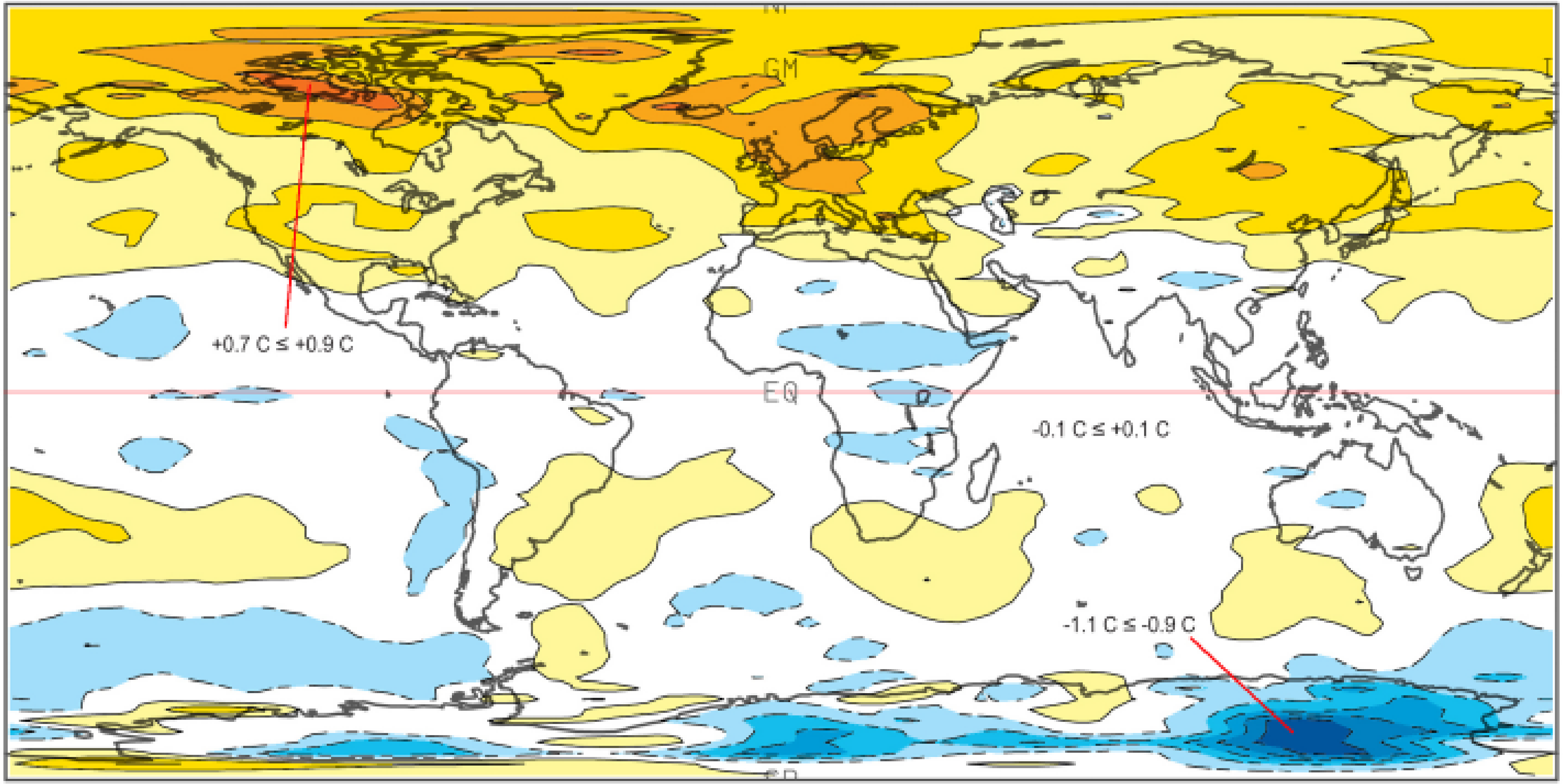
Ironically, actions that artificially inflate the cost of energy might hamper those efforts, as healthy economies can better afford to find and develop alternative energy sources and cleaner energy technologies.

We should also enhance the national and international infrastructure for dealing with climate and weather events, including droughts, floods, hurricanes and tornadoes. We know these events will continue to happen whether the climate changes or not. Everyone would benefit if we were better prepared when they happen.

Finally, we recognize that climate change is real and that human activities are probably contributing to that change. We should continue to devote resources to monitoring and studying the climate system, so we can develop the systems that will let us know what the climate is doing and respond appropriately. Perhaps, at some point in the future, we might even be able to reliably forecast what the climate will do in future generations.

— Dr. John R. Christy & Dr. Roy Spencer
Earth System Science Center
The University of Alabama in Huntsville

Regional tropospheric temperature trends, 12/78 through 10/93



CONTOUR FROM -1.7000 TO 1.7000 CONTOUR INTERVAL OF 0.20000 PT(3,3)= 0.15833

Broken lines outline areas of cooling; solid lines outline areas of warming.
Each contour represents 0.2 Celsius, starting at -0.1 and +0.1 degrees C.

Dr. John Christy

Dr. John R. Christy is professor of atmospheric science and director of the Earth System Science Center at the University of Alabama in Huntsville, where he began studying global climate issues in 1987.

In November 2000 Gov. Don Siegelman appointed him to be Alabama's state climatologist.

In 1989 Dr. Roy W. Spencer (then a space scientist at NASA's Marshall Space Flight Center and now a principle research scientist at UAH) and Christy developed a global temperature dataset from microwave data observed from satellites beginning in November 1978. For this achievement, Spencer and Christy were awarded NASA's Medal for Exceptional Scientific Achievement in 1991. In 1996 they received a special award by the American Meteorological Society "for developing a global, precise record of earth's temperature from operational polar-orbiting satellites, fundamentally advancing our ability to monitor climate." In January 2002 Christy was inducted as a fellow of the American Meteorological Society.

Christy has served as a contributor (1992, 1994 and 1996) and lead author (2001) for the U.N. reports by the Intergovernmental Panel on Climate Change, in which the satellite temperatures were included as a high-quality data set for studying global climate change. He has or is serving on five National Research Council panels or committees and has performed research funded by NASA, NOAA, DOE, DOT and the State of Alabama and has published studies appearing in *Science*, *Nature*, the *Journal of Climate* and *The Journal of Geophysical Research*. He has testified before several congressional committees.

Christy received M.S. and Ph.D. degrees in atmospheric sciences from the University of Illinois (1984, 1987). Prior to this career path he had graduated from the California State University in Fresno (B.A. Mathematics, 1973) and taught physics and chemistry for two years as a missionary teacher in Nyeri, Kenya. After earning a Master of Divinity degree from Golden Gate Baptist Seminary (1978) he served four years as a bivocational mission-pastor in Vermillion, South Dakota, where he also taught college math.

Christy is married to the former Babs Joslin, a fellow missionary he met in Kenya. They have two children.

Christy's favorite hobby is panning for gold, a skill he learned as a teenager in California. He also runs, completing races from two to 31.1 miles in the past year.

Dr. Roy Spencer

Dr. Roy Spencer is a principal research scientist in the Earth System Science Center at The University of Alabama in Huntsville.

He is the U.S. science team leader for the Advanced Microwave Scanning Radiometer flying on NASA's Aqua satellite.

He was a space scientist at NASA's Marshall Space Flight Center in 1989, when he teamed with Dr. John Christy to develop a system to measure global climate trends using microwave sensors aboard NOAA satellites.

Spencer and Christy were awarded NASA's Medal for Exceptional Scientific Achievement in 1991. In 1996 they received a special award by the American Meteorological Society "for developing a global, precise record of earth's temperature from operational polar-orbiting satellites, fundamentally advancing our ability to monitor climate."

At NASA Spencer directed research into developing and applying satellite microwave remote sensing systems for measuring global temperatures, water vapor and precipitation. In 1997 he was named senior scientist for climate studies at NASA/MSFC.

He earned M.S. and Ph.D. degrees in meteorology (1979, 1981) from the University of Wisconsin, Madison, and was an assistant scientist in the Space Science and Engineering Center in Madison, WI, for more than a year. He was a Universities' Space Research Association visiting scientist at NASA/MSFC from 1984 to 1987.

Spencer has testified in both the U.S. House of Representatives and the U.S. Senate on the subject of global warming.

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Monthly means of lower troposphere LT5.1

DECADAL TREND, 1978 - 2003 =
Global: 0.076 NH: 0.147 SH: 0.006
(*in degrees Celsius*)
Deviations from seasonal norms, based on 79.001-98.365

YR.	MON	GLOBAL	NH	SH	No.Days
1978	12	-0.177	-0.120	-0.234	31.
1979	1	-0.124	-0.242	-0.005	31.
1979	2	-0.119	-0.175	-0.063	28.
1979	3	-0.116	-0.105	-0.128	31.
1979	4	-0.146	-0.161	-0.132	30.
1979	5	-0.143	-0.219	-0.068	31.
1979	6	-0.131	-0.172	-0.091	30.
1979	7	-0.028	0.085	-0.141	31.
1979	8	-0.119	-0.075	-0.162	31.
1979	9	0.041	0.018	0.064	30.
1979	10	0.151	0.105	0.196	31.
1979	11	0.030	0.083	-0.022	25.
1979	12	0.128	0.160	0.096	31.
1980	1	0.053	-0.098	0.204	25.
1980	2	0.143	0.065	0.221	29.
1980	3	0.038	-0.176	0.252	31.
1980	4	0.169	-0.008	0.346	30.
1980	5	0.181	0.053	0.309	31.
1980	6	0.119	0.058	0.180	30.
1980	7	0.087	0.041	0.132	31.
1980	8	0.149	0.047	0.252	31.
1980	9	0.204	0.070	0.339	30.
1980	10	0.106	0.161	0.052	31.
1980	11	0.138	0.150	0.127	30.
1980	12	-0.045	-0.070	-0.020	30.
1981	1	0.153	0.149	0.156	31.
1981	2	0.196	0.098	0.295	28.
1981	3	0.159	0.163	0.155	25.
1981	4	0.023	0.098	-0.052	21.
1981	5	0.065	0.093	0.037	31.
1981	6	-0.010	0.044	-0.065	30.
1981	7	0.063	0.036	0.091	31.
1981	8	0.072	0.109	0.036	23.
1981	9	0.043	0.001	0.086	30.
1981	10	0.005	0.054	-0.043	31.
1981	11	0.011	0.019	0.003	30.
1981	12	0.149	0.127	0.170	31.
1982	1	-0.077	-0.198	0.043	31.
1982	2	-0.071	-0.171	0.029	28.
1982	3	-0.214	-0.342	-0.086	31.
1982	4	-0.110	-0.019	-0.202	30.
1982	5	-0.133	-0.271	0.005	31.
1982	6	-0.093	-0.233	0.046	30.
1982	7	-0.238	-0.228	-0.248	31.
1982	8	-0.158	-0.266	-0.050	31.
1982	9	-0.132	-0.232	-0.032	24.
1982	10	-0.212	-0.327	-0.096	31.
1982	11	-0.108	-0.397	0.181	30.
1982	12	0.010	-0.030	0.049	31.
1983	1	0.150	0.159	0.141	31.
1983	2	0.007	-0.133	0.147	28.
1983	3	0.274	0.205	0.344	31.
1983	4	0.183	0.013	0.353	30.
1983	5	0.196	-0.005	0.396	31.
1983	6	-0.079	-0.182	0.024	30.
1983	7	0.127	0.135	0.118	31.
1983	8	0.088	0.096	0.079	31.
1983	9	0.084	0.035	0.133	30.
1983	10	-0.087	-0.161	-0.014	31.
1983	11	-0.025	0.039	-0.089	30.
1983	12	-0.296	-0.304	-0.287	31.
1984	1	-0.301	-0.353	-0.249	28.
1984	2	-0.183	-0.301	-0.065	29.
1984	3	-0.116	-0.322	0.090	31.
1984	4	-0.221	-0.327	-0.115	27.
1984	5	-0.044	-0.213	0.124	31.
1984	6	-0.242	-0.190	-0.293	30.
1984	7	-0.274	-0.310	-0.238	31.
1984	8	-0.195	-0.182	-0.207	31.
1984	9	-0.501	-0.475	-0.526	30.
1984	10	-0.200	-0.266	-0.135	31.
1984	11	-0.408	-0.580	-0.236	30.
1984	12	-0.371	-0.570	-0.171	28.
1985	1	-0.133	-0.183	-0.082	31.
1985	2	-0.185	-0.107	-0.263	28.
1985	3	-0.081	-0.260	0.098	31.
1985	4	-0.161	-0.270	-0.053	30.
1985	5	-0.210	-0.177	-0.243	31.
1985	6	-0.210	-0.320	-0.099	30.
1985	7	-0.347	-0.524	-0.170	27.
1985	8	-0.172	-0.350	0.006	31.
1985	9	-0.170	-0.311	-0.030	27.
1985	10	-0.264	-0.282	-0.246	31.
1985	11	-0.115	-0.084	-0.146	27.
1985	12	-0.117	-0.041	-0.193	31.
1986	1	-0.006	0.026	-0.038	31.
1986	2	-0.139	-0.288	0.009	28.
1986	3	-0.115	-0.130	-0.099	28.
1986	4	0.009	-0.049	0.067	30.
1986	5	-0.010	-0.076	0.056	31.
1986	6	-0.114	-0.094	-0.135	30.
1986	7	-0.149	-0.230	-0.068	31.
1986	8	-0.183	-0.248	-0.117	31.
1986	9	-0.236	-0.320	-0.151	30.
1986	10	-0.238	-0.241	-0.235	31.
1986	11	-0.078	-0.194	0.038	30.
1986	12	-0.105	-0.190	-0.019	31.
1987	1	0.176	0.278	0.073	31.
1987	2	0.219	0.304	0.135	28.
1987	3	-0.050	0.011	-0.112	31.
1987	4	0.130	0.064	0.196	30.
1987	5	-0.033	-0.104	0.039	31.
1987	6	0.156	0.049	0.264	30.
1987	7	0.129	0.115	0.144	28.
1987	8	0.043	-0.002	0.087	31.

Monthly means of lower troposphere LT5.1

Deviations from seasonal norms, based on 79.001-98.365

YR.	MON	GLOBAL	NH	SH	No.Days
1987	9	0.061	0.129	-0.007	30.
1987	10	0.227	0.234	0.220	31.
1987	11	0.125	0.106	0.145	30.
1987	12	0.387	0.558	0.216	31.
1988	1	0.302	0.382	0.222	31.
1988	2	0.051	0.076	0.027	24.
1988	3	0.252	0.226	0.277	31.
1988	4	0.078	-0.024	0.179	30.
1988	5	0.103	0.213	-0.007	31.
1988	6	0.100	0.130	0.070	27.
1988	7	0.202	0.265	0.139	31.
1988	8	0.157	0.298	0.016	31.
1988	9	0.296	0.316	0.275	30.
1988	10	0.142	0.196	0.088	31.
1988	11	-0.043	-0.092	0.005	30.
1988	12	-0.103	-0.103	-0.103	31.
1989	1	-0.297	-0.319	-0.275	31.
1989	2	-0.152	-0.117	-0.187	28.
1989	3	-0.165	-0.058	-0.272	31.
1989	4	-0.083	0.046	-0.211	30.
1989	5	-0.199	-0.108	-0.290	31.
1989	6	-0.196	-0.134	-0.258	30.
1989	7	-0.075	-0.028	-0.122	31.
1989	8	-0.058	-0.046	-0.069	31.
1989	9	0.080	0.114	0.047	29.
1989	10	0.066	0.069	0.062	31.
1989	11	-0.037	-0.155	0.082	30.
1989	12	0.091	0.044	0.137	31.
1990	1	0.022	-0.011	0.054	31.
1990	2	-0.111	-0.004	-0.219	28.
1990	3	0.131	0.358	-0.095	31.
1990	4	0.030	0.091	-0.031	30.
1990	5	0.115	0.187	0.042	31.
1990	6	0.106	0.251	-0.039	30.
1990	7	0.065	0.011	0.118	31.
1990	8	0.026	0.066	-0.015	31.
1990	9	0.012	0.063	-0.039	30.
1990	10	0.147	0.155	0.138	31.
1990	11	0.339	0.324	0.355	30.
1990	12	0.234	0.269	0.198	31.
1991	1	0.150	0.194	0.105	31.
1991	2	0.185	0.220	0.149	28.
1991	3	0.308	0.457	0.159	31.
1991	4	0.149	0.248	0.049	30.
1991	5	0.180	0.340	0.020	29.
1991	6	0.343	0.319	0.367	30.
1991	7	0.206	0.219	0.192	31.
1991	8	0.221	0.225	0.217	31.
1991	9	0.067	0.149	-0.015	30.
1991	10	-0.065	-0.016	-0.115	31.
1991	11	-0.111	-0.011	-0.210	30.
1991	12	-0.136	-0.153	-0.118	31.
1992	1	-0.038	0.001	-0.077	31.
1992	2	-0.144	-0.040	-0.247	29.
1992	3	-0.035	-0.050	-0.019	31.
1992	4	-0.215	-0.311	-0.118	30.
1992	5	-0.225	-0.444	-0.006	31.
1992	6	-0.236	-0.430	-0.042	30.
1992	7	-0.372	-0.600	-0.144	31.
1992	8	-0.406	-0.483	-0.330	31.
1992	9	-0.390	-0.359	-0.420	30.
1992	10	-0.167	-0.227	-0.107	31.
1992	11	-0.176	-0.134	-0.217	30.
1992	12	-0.242	-0.139	-0.345	31.
1993	1	-0.255	-0.206	-0.304	31.
1993	2	-0.219	-0.110	-0.327	28.
1993	3	-0.386	-0.317	-0.455	31.
1993	4	-0.274	-0.325	-0.223	30.
1993	5	-0.231	-0.206	-0.255	31.
1993	6	-0.118	-0.167	-0.070	30.
1993	7	-0.098	-0.156	-0.040	31.
1993	8	-0.209	-0.254	-0.163	31.
1993	9	-0.359	-0.428	-0.291	30.
1993	10	-0.116	-0.210	-0.021	31.
1993	11	-0.099	-0.177	-0.022	30.
1993	12	0.040	0.089	-0.008	31.
1994	1	-0.032	0.082	-0.145	31.
1994	2	-0.187	-0.147	-0.227	28.
1994	3	-0.191	-0.077	-0.306	31.
1994	4	-0.133	0.007	-0.273	30.
1994	5	-0.134	0.070	-0.338	31.
1994	6	-0.024	0.029	-0.077	30.
1994	7	-0.036	0.050	-0.122	31.
1994	8	-0.096	-0.028	-0.164	31.
1994	9	0.011	0.077	-0.055	30.
1994	10	-0.163	0.030	-0.356	31.
1994	11	0.110	0.221	0.000	30.
1994	12	0.086	0.105	0.067	31.
1995	1	0.102	0.353	-0.149	31.
1995	2	0.046	0.289	-0.197	28.
1995	3	-0.058	-0.008	-0.108	31.
1995	4	0.193	0.352	0.033	30.
1995	5	0.045	0.201	-0.111	31.
1995	6	0.111	0.295	-0.073	30.
1995	7	0.075	0.116	0.033	31.
1995	8	0.234	0.324	0.145	31.
1995	9	0.239	0.318	0.159	30.
1995	10	0.107	0.092	0.121	31.
1995	11	0.111	0.334	-0.112	30
1995	12	-0.161	-0.330	0.007	31.
1996	1	-0.155	-0.111	-0.200	31.
1996	2	-0.005	-0.029	0.020	29.
1996	3	0.007	-0.059	0.074	31.
1996	4	-0.067	-0.254	0.119	30.
1996	5	-0.133	-0.085	-0.181	31.
1996	6	-0.137	-0.092	-0.182	30.
1996	7	-0.033	-0.016	-0.051	31.
1996	8	0.069	-0.096	0.234	31.

Monthly means of lower troposphere LT5.1

Deviations from seasonal norms, based on 79.001-98.365

YR.	MON	GLOBAL	NH	SH	No.Days
1996	9	0.162	0.027	0.298	30.
1996	10	0.080	0.054	0.107	31.
1996	11	0.072	0.261	-0.117	30.
1996	12	-0.034	0.044	-0.112	31.
1997	1	-0.143	-0.271	-0.016	31.
1997	2	-0.096	-0.110	-0.082	28.
1997	3	-0.107	-0.070	-0.144	31.
1997	4	-0.222	-0.145	-0.299	30.
1997	5	-0.073	-0.053	-0.094	31.
1997	6	-0.016	0.048	-0.079	30.
1997	7	0.067	0.181	-0.046	31.
1997	8	0.062	0.211	-0.087	31.
1997	9	0.101	0.290	-0.087	30.
1997	10	0.132	0.179	0.085	31.
1997	11	0.146	0.051	0.241	30.
1997	12	0.262	0.180	0.344	31.
1998	1	0.499	0.484	0.514	31.
1998	2	0.646	0.687	0.605	28.
1998	3	0.448	0.537	0.360	31.
1998	4	0.746	0.997	0.496	30.
1998	5	0.624	0.669	0.578	31.
1998	6	0.551	0.646	0.455	30.
1998	7	0.490	0.681	0.298	31.
1998	8	0.474	0.533	0.416	31.
1998	9	0.428	0.566	0.291	30.
1998	10	0.380	0.500	0.259	31.
1998	11	0.136	0.195	0.077	30.
1998	12	0.241	0.308	0.174	31.
1999	1	0.087	0.232	-0.058	31.
1999	2	0.174	0.308	0.041	28.
1999	3	-0.088	-0.010	-0.166	31.
1999	4	0.001	0.299	-0.296	30.
1999	5	-0.071	0.093	-0.235	31.
1999	6	-0.194	0.063	-0.450	30.
1999	7	-0.073	0.042	-0.188	31.
1999	8	-0.111	-0.020	-0.201	31.
1999	9	0.074	0.191	-0.043	30.
1999	10	0.014	0.014	0.014	31.
1999	11	-0.036	0.151	-0.222	30.
1999	12	-0.035	0.159	-0.229	31.
2000	1	-0.273	-0.197	-0.350	31.
2000	2	-0.057	0.019	-0.134	29.
2000	3	-0.048	-0.021	-0.075	31.
2000	4	0.050	0.226	-0.125	30.
2000	5	0.023	0.084	-0.039	31.
2000	6	-0.028	0.019	-0.074	30.
2000	7	-0.097	-0.010	-0.183	31.
2000	8	-0.107	0.077	-0.291	31.
2000	9	0.057	0.156	-0.041	30.
2000	10	0.029	0.033	0.025	31.
2000	11	0.031	0.011	0.051	30.
2000	12	-0.001	0.024	-0.027	31.
2001	1	0.016	0.068	-0.037	31.
2001	2	0.098	-0.023	0.219	28.
2001	3	0.043	0.177	-0.090	31.
2001	4	0.190	0.236	0.144	30.
2001	5	0.161	0.331	-0.009	31.
2001	6	-0.044	0.076	-0.164	30.
2001	7	0.047	0.182	-0.087	31.
2001	8	0.261	0.440	0.083	30.
2001	9	0.118	0.216	0.020	30.
2001	10	0.220	0.213	0.226	31.
2001	11	0.219	0.284	0.154	30.
2001	12	0.218	0.207	0.230	31.
2002	1	0.300	0.397	0.203	31.
2002	2	0.280	0.393	0.166	28.
2002	3	0.262	0.370	0.155	31.
2002	4	0.239	0.214	0.265	30.
2002	5	0.267	0.268	0.267	31.
2002	6	0.280	0.329	0.231	30.
2002	7	0.213	0.384	0.042	31.
2002	8	0.180	0.151	0.210	31.
2002	9	0.281	0.281	0.281	30.
2002	10	0.155	-0.034	0.344	31.
2002	11	0.290	0.248	0.332	30.
2002	12	0.183	0.029	0.337	31.
2003	1	0.365	0.459	0.271	31.
2003	2	0.252	0.171	0.333	28.
2003	3	0.103	0.088	0.119	31.
2003	4	0.135	0.252	0.019	30.
2003	5	0.182	0.375	-0.012	31.
2003	6	-0.012	0.168	-0.192	30.
2003	7	0.081	0.147	0.015	31.
2003	8	0.089	0.286	-0.108	31.
2003	9	0.173	0.313	0.033	30.
2003	10	0.271	0.410	0.132	31.
2003	11	0.194	0.259	0.129	30.

UAH
The University of Alabama in Huntsville
Earth System Science Center

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For Additional Information:
Dr. John Christy, UAH, (256) 961-7763
christy@nsstc.uah.edu
Dr. Roy Spencer, UAH, (256) 961-7960
roy.spencer@msfc.nasa.gov

Global Temperature Report: November 2003

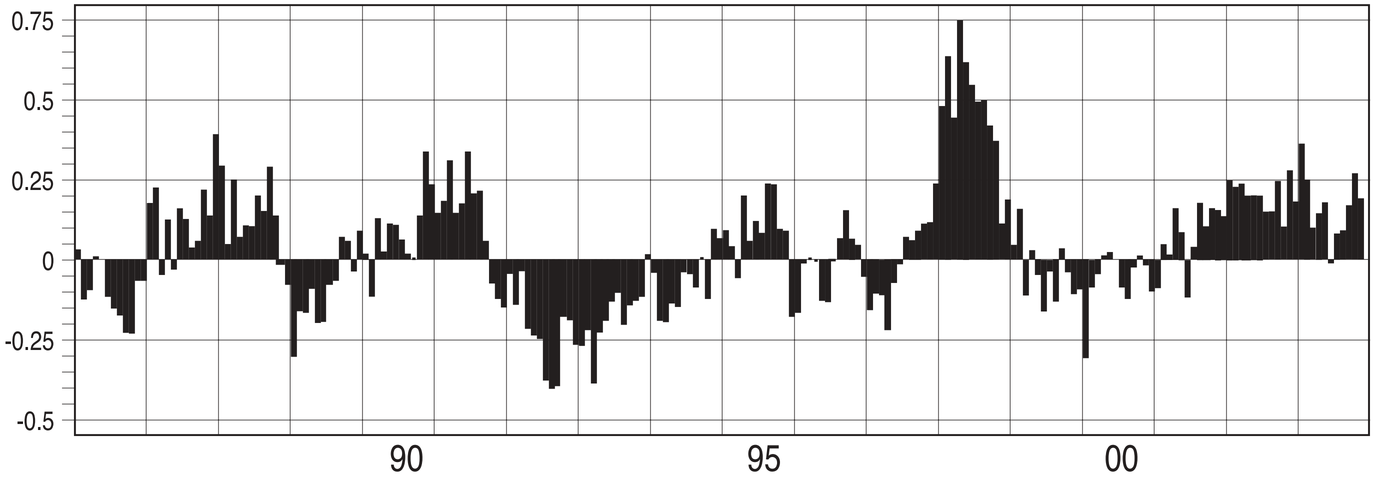

Fig. 1: Global temperature variation, in Celsius; trend since Nov. 16, 1978, +0.076° C per decade

Global composite temp.:	+0.19 C (about 0.34° Fahrenheit) above 20-year average for November.
Northern Hemisphere:	+0.26 C (about 0.47° Fahrenheit) above 20-year average for November.
Southern Hemisphere:	+0.13 C (about 0.23° Fahrenheit) above 20-year average for November.

October temperatures (revised): Global Composite:	+0.27 C above 20-year average
Northern Hemisphere:	+0.41 C above 20-year average
Southern Hemisphere:	+0.13 C above 20-year average

(All temperature variations are based on a 20-year average (1979-1998) for the month reported.)

Notes on data released Dec. 8, 2003:

The November 2003 temperature data completes 25 years of global atmospheric temperature monitoring by microwave sounding units aboard National Oceanic and Atmospheric Administration satellites.

During that quarter century, Earth's atmosphere has warmed about 0.19 degrees Celsius, or 0.34° Fahrenheit. The bulk of that warming, however, was in the northernmost third of the globe: The Northern Hemisphere warmed by

0.37 C (about 0.66° F) while the Southern Hemisphere warmed only 0.015 C or approximately 0.027° F.

This data may soon be available on-line at: http://www.uah.edu/News/climate/

A color graphic showing Earth's atmospheric temperature anomalies during the past month should soon be available at:

http://wwwghcc.msfc.nasa.gov/temperature/

As part of an ongoing joint project between UAH, NOAA and NASA, Dr. John Christy, director of the Earth System Science Center (ESSC) at The University of Alabama in Huntsville, and Dr. Roy Spencer, an ESSC principal research scientist, use data gathered by microwave sounding units on NOAA satellites to get accurate temperature readings for almost all regions of the Earth. This includes remote desert, ocean and rain forest areas for which reliable climate data are not otherwise available.

The satellite-based instruments measure the temperature of the atmosphere from the surface up to an altitude of about eight kilometers above sea level.

Once the monthly temperature data is collected and processed, it is placed in a "public" computer file for immediate access by atmospheric scientists in the U.S. and abroad.

Neither Spencer nor Christy receives any research support or funding from oil, coal or industrial companies or organizations, or from any private or special interest groups. All of their climate research funding comes from state and federal grants or contracts.