

Surface temperatures are rising, but probably not as quickly as is claimed.

Global Warming: Correcting the Data

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All historical temperature records agree: the planet is warmer than it was. But those histories are subject to a number of biases, some of which are obvious while others are very subtle. The most obvious bias is that weather stations in cities do not need “global warming” in order to report warmer temperatures. The city’s ever-increasing amounts of bricks, buildings, and pavement retain heat, absorb more of the sun’s energy, and impede the flow of ventilating winds. There is nothing new about this type of local warming, which is quite distinct from a wholesale warming of the planetary surface.

These two concepts, global and locally induced warming, were first elucidated in a landmark paper published in 1933 by J. B. Kincer, titled “Is Our Climate Changing? A Study of Long-Term Temperature Trends.” Kincer worked for the U.S. Weather Bureau (forerunner of today’s National Weather Service) and published his paper in the journal *Monthly Weather Review*. Since then, scientists studying global temperature history have taken pains to remove the biases caused by “urban warming.”

CORRECTING THE RECORD

In principle, this correction is simple. Compare two neighboring weather stations. Their temperatures should oscillate in unison from year-to-year. But if one station displays a warming trend when the other does not, then the first station is assumed to be contaminated by “urban bias.”

Many attempts have been made to deal with this and other factors that can bias a temperature history. Thomas Karl of the U.S. National Climatic Data Center published a landmark

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paper relating population levels and “artificial” warming in the *Journal of Climate* in 1987. Karl then developed what he called the “Historical Climate Network” (HCN) to gather temperature data that would be free of bias.

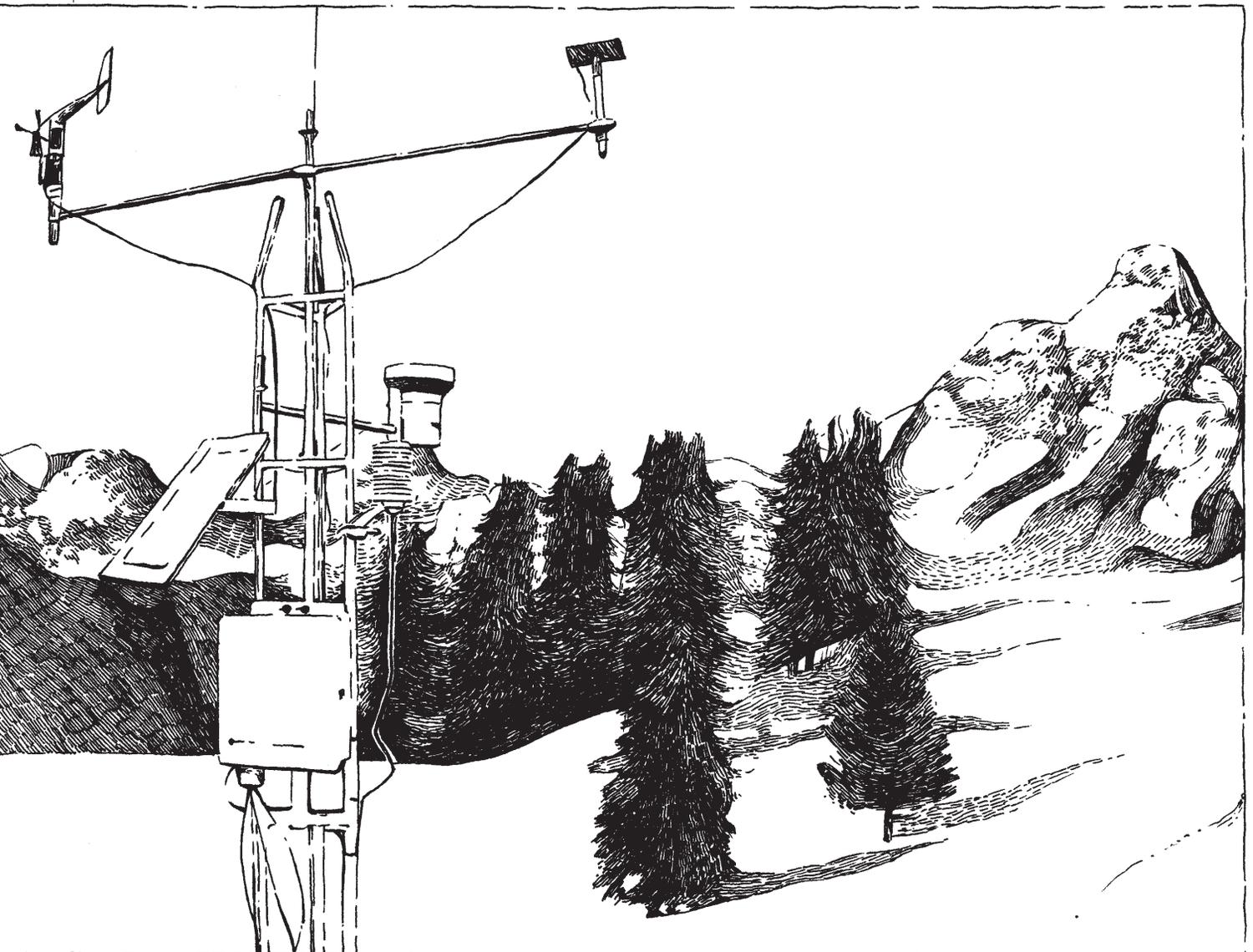
Prior to the HCN, the (lower-48) U.S. average temperature was computed by averaging the temperature readings from 344 multi-county aggregates, known as “climatological divisions” (CDs). There are currently 11,000 individual weather stations run mainly by “cooperative observers” who are usually individuals from families with a long history of staying in one place. They are provided equipment by the National Weather Service and they report their data to the National Climatic Data Center in Asheville, N.C. Their data, along with a few National Weather Service and airport locations, populate the CD record.

The CD records were simple averages of all readings from all the stations within each division. The records were contaminated by many factors. For example, sometimes the instruments were moved, or a tree shaded the weather station, or a new, nearby parking lot was built. Aside from the urban effect, the HCN attempted to account for the other biasing factors by looking for “discontinuities” in histories, indicating

some sudden site-related changes, as well as changes in the time of observation during the day.

How can the time of observation of the day’s mean temperature (the average of the high and the low for the previous 24 hours) bias a long-term temperature history? Almost all cooperative observer stations now contain electronic thermometers that automatically record the high and low temperature for each 24-hour period beginning at midnight. But historically, highs and lows were recorded “manually” at approximately the same time each day. Thermometers had mechanical stops in them that displayed the high and low temperatures until they were manually reset. Observers would choose a time, usually in the morning or the late afternoon, to record and reset. The fact that most observers chose the early morning introduced a very subtle “time-of-day” bias into the histories. Mean daily temperatures taken the “old-fashioned” way turn out to be colder than they actually were. Imagine recording the temperature on a record-breaking cold winter morning. The result? Two record lows, one recorded at 7:00 a.m. today, when winter temperatures are their lowest, and the second recorded at 7:01 a.m., one minute after the thermometer was reset. Likewise, afternoon observers’

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records were artificially warm, but there were fewer afternoon observers than morning ones.

Figure 1 shows the CD and the HCN histories. The differences look small until one subtracts the CD values from the HCN, as shown in Figure 2. The differences, in terms of percent of warming, are large, with the HCN warming 34 percent greater than the CD (1.34°F vs. 0.85°F; 0.74°C vs. 0.47°C) for the period 1895–2007. In other words, in a comprehensive attempt to remove biases from the original CD records, the HCN actually exhibits more warming.

The differences between HCN and CD temperatures are typical of what we see when temperature histories are revised. Six major revisions in global temperature histories all have shown more warming than existed before each revision. Those revisions included adjustments of satellite data for calibration between various instruments, revising weather balloon data based upon new criteria for data quality, and internal adjustments of the United Nations’ global temperature histories.

TESTING THE DATA

To examine the validity of the revisions to the surface temperature data, University of Guelph environmental economist Ross McKittrick and I estimated several regression models to test whether the variation in surface temperature across sites around the world was related to non-climatic socioeconomic variables. An accurate surface temperature record free of contaminants should have no statistical relationship with socioeconomic variables and instead should reflect only known physical and thermodynamic factors.

In its 2007 report on climate change, the United Nations’ Intergovernmental Panel on Climate Change (IPCC), which claims to represent the consensus of climate scientists, brushes aside any potential systematic bias in its own temperature history. That assertion seems worth further investigation. Two successive revisions of the IPCC’s temperature history, published in its 2001 and 2007 science compendia, both create more warming out of what are essentially the same data.

We examined two sets of data “gridded” into 5° × 5° latitude-longitude boxes: the surface data used by the IPCC and temperatures sensed from satellites. The latter data were originally published by Roy Spencer and John Christy in 1990 and are often referred to as the “UAH” record, for the University of Alabama-Huntsville where the dataset was developed. The data are continually updated and revised. The versions of each record that we used were the most recent ones available when we wrote our scientific manuscript in 2005. Our study begins in 1979, which is when the satellite record starts, and ends in 2002.

LAND OBSERVATIONS We examine only land temperatures. Land areas should respond more to changes in the climate “forcing” factors, such as the greenhouse effect, than oceanic regions, for two reasons:

First, temperature responds most to the first increments of a greenhouse gas, or to the first increments of greenhouse gases that act similarly in the atmosphere. Water vapor and carbon dioxide, in fact, absorb some of the same radiation from the earth’s surface; consequently, if an atmosphere is initially poor in both, then the first increments of either will result in stronger warming than latter increments. The world’s continental areas are good candidates that demonstrate this phenomenon. Obviously the entire world had relatively less (compared to today) carbon dioxide concentration prior to the major industrialization asso-

Figure 1

U.S. Annual Average Temperature

Temperature measures from CD and HCN monitors

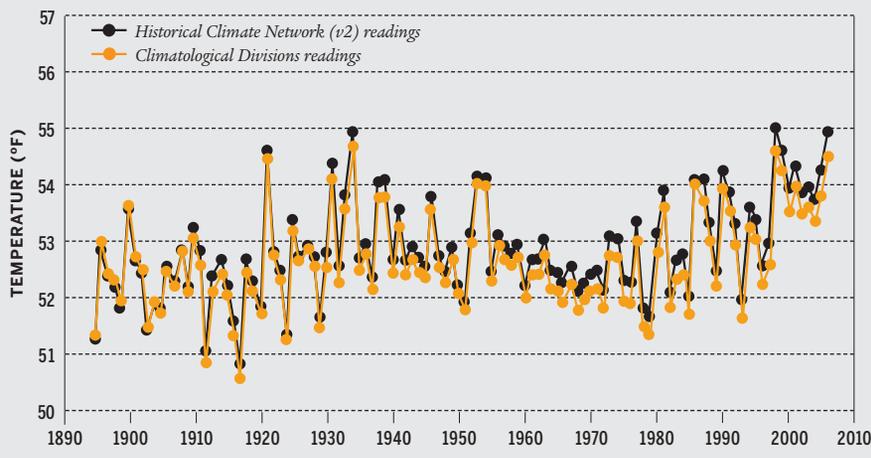
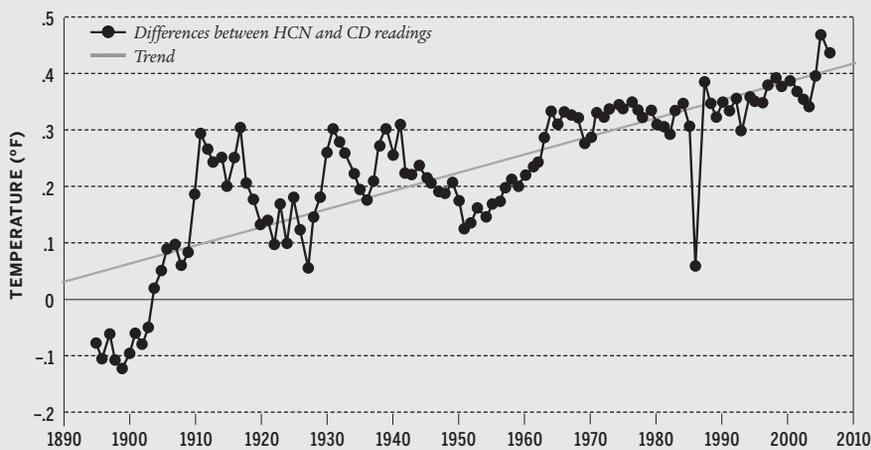


Figure 2

Temperature Differences

Differences between HCN and CD observations



ciated with World War II and its aftermath. Consequently, dry land areas, especially those far removed from oceans, will display a relatively rapid warming compared to what would be observed in the moist air masses over the world's oceans.

Second, temperatures over land areas respond more rapidly to changes in radiation than do temperatures over the ocean. This is rather obvious, as land becomes warmer than the ocean in the summer and colder in the winter.

Scientists expect that warming trends observed over land areas will generally be greater than those over the ocean. During our study period, the IPCC surface history (determined by our gridcell system and subject to the sampling limitations

very little attention, but could be quite important. Does a poor nation maintain its weather stations as well as a wealthy one? It seems logical that, where per-capita income is low, the maintenance and proper operation of a weather station are unlikely to be high-priority items. This can easily result in some sort of warming bias. For example, in order to provide comparable data, weather stations are supposed to meet standards proposed by the United Nations' World Meteorological Organization. One of the organization's requirements is that the shelters for thermometers be painted a bright shade of white. White objects absorb less energy than darker ones (which is why people in the torrid Middle East tend to wear white).

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described in the next paragraph) shows land-based warming of an average of 0.27°C (0.49°F) per decade, while overall global warming, because of the prevalence of ocean, is 0.17°C (0.31°F) per decade. Assuming 70 percent of the surface of the earth is ocean, this yields a surface atmospheric warming rate over the ocean of 0.12°C (0.22°F) per decade, or slightly less than half of the land rate in our study.

There were 469 latitude-longitude boxes over land areas in the IPCC record. We required each box to have data for at least 90 percent of the 23 years that we examined, and we considered a year intact if there were at least eight months of data. That left 451 boxes. We did not concern ourselves with the possibility of urban warming in Antarctica because there is precious little land-use change, and besides the international scientific teams that monitor the Antarctic stations likely produce data of high quality. Omitting Antarctica left us with 440 boxes. Of those, 348 were in the Northern Hemisphere and 92 in the Southern, which should not be surprising as there is more land area and more quality data in the Northern Hemisphere. Quality data are especially sparse in many parts of South America and Africa, largely in the Southern Hemisphere.

BIASES The IPCC record is a global history of surface temperatures measured at weather stations around the planet. The UAH record is different. The satellites do not directly measure surface temperature, but their data can be used to estimate the temperature of the lower atmosphere, known as the troposphere. While the IPCC record may contain some urban bias, the satellite record cannot.

We were interested in finding as many “extraneous” biases as we could, whether derived from urbanization, changes in land-use (such as changing forest land into farmland), or “economic” factors. All of those biases should be absent in the satellite data.

The last source of bias — economic factors — has received

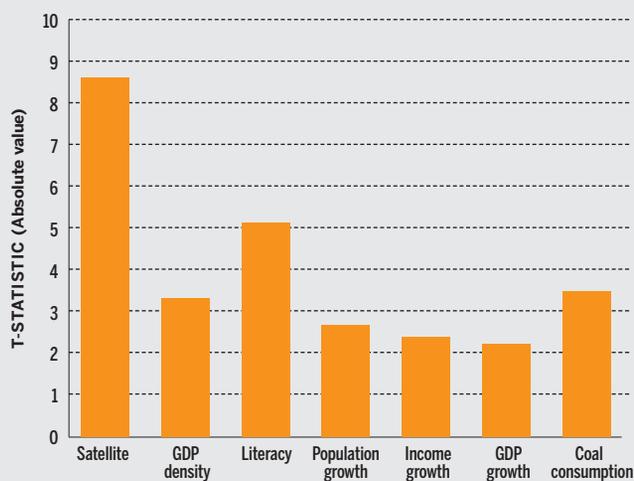
Therefore, as the paint on a thermometer shelter begins to darken with age, the temperature inside the shelter will read higher. Would regular painting of weather stations be a high priority in a poor country?

One sign that economic factors may be degrading temperature records concerns the number of weather stations. The “Global HCN,” an international version of Karl’s U.S. HCN, peaked with 6,000 weather stations in the late 1960s. By the late 1990s, the number of quality stations had dropped to less than 3,000. The number of stations was almost halved in the early 1990s concurrent with the collapse of the Soviet Union, though the loss was not confined to that nation.

Figure 3

Climatic and Non-Climatic Warming

Relative confidence of various predictors



NOTE: 95% confidence at 1.96; 99% confidence at 2.58

AN ECONO-CLIMATE MODEL

We built a series of mathematical models designed to explain differences in IPCC warming trends between grid boxes as a function of climatic and geographic factors, human-induced surface processes, and economically determined effects.

The climate and geography-based models are quite simple and come in different versions. We specified a number of climate variables, the most important and obvious one being the satellite-measured temperature over the same IPCC surface-measured gridcell. We also included mean atmospheric surface pressure as an indicator of potential warming. (I had pre-

ed this type of bias could not be supported. In this and in every model version that included satellite data, the satellite was by far the most important predictor of the surface temperature trend. But population growth was also highly significant. The greater the population growth, the greater the warming — even though the bias had supposedly been scrubbed from the data.

We then modeled the issues of data quality that would be affected by economic conditions and left out the surface process data. The predictors included 1979 GDP per unit area, literacy rate for the country containing the grid box, and the number of missing months in stations that met our mini-

The probability that the socioeconomic factors (as a group) were not important was less than one in 14 trillion.

viously demonstrated that the amount of regional warming is directly proportional to the amount of cold, dry air, which is related to barometric pressure.) We also included latitude and an indicator of the proximity to an ocean.

As might be expected, the satellite-sensed temperature was a highly significant predictor. In fact, none of the other geographic variables were significant if the satellite data were used. However, if the satellite data were not included, the dryness/sea level pressure combination and latitude became highly significant, indicating that the satellite-sensed data were a very good proxy for the general climate of the land regions.

We then added the surface process data, consisting of population growth, income growth, real GDP change, and coal consumption. The population data were highly significant. In other words, the IPCC's contention that it had successfully eliminat-

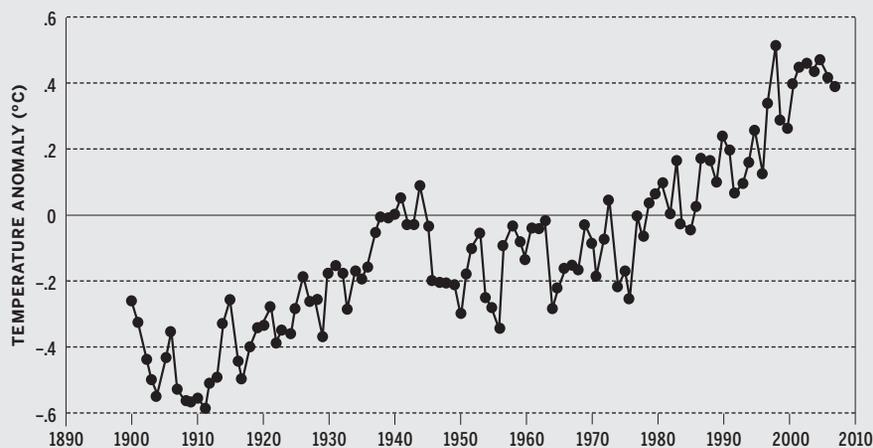
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Figure 4

Global Average Surface Temperature Anomalies (IPCC) 1900–2007



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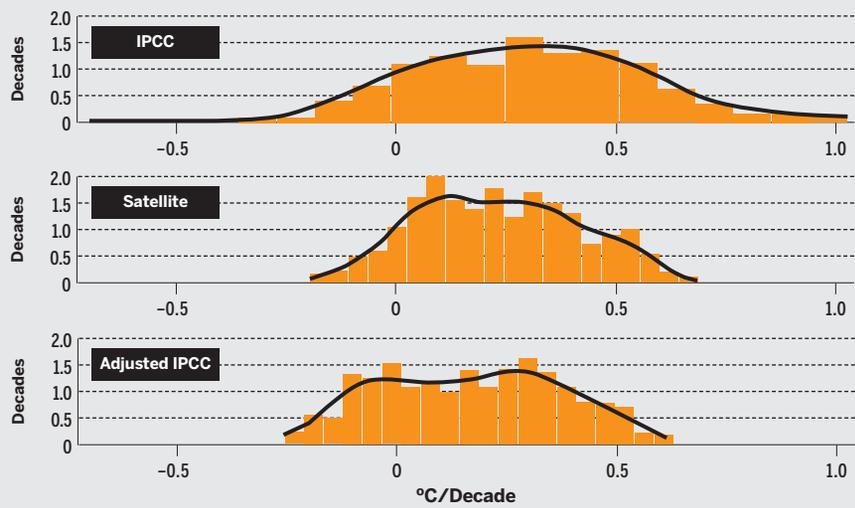
COMPARISON MODELING What happens if we eliminate the UAH satellite temperature data from the model? The geographic/climate variables become significant, but the socioeconomic measures do not change at all.

Some 53 percent of the geographic distribution of surface trends are explained when all four classes of variables are included simultaneously (satellite temperature trends, physical/geographic factors, economic factors, and measures of data quality). But only 34 percent is

Figure 5

Decades of Warming (or Cooling)

Frequency distribution of observed trends by data set



explained when the information given by the satellite trend for the grid box is removed. This is a reduction of the overall explanatory power by about one-third of that in the full model.

In the model without the satellite temperature data, almost all — 85 percent — of the explanatory power is from the socioeconomic predictors. Given that the model explains only 34 percent of the total variation of the IPCC temperature trends, this means that non-climatic factors could be responsible for about 29 percent (0.85×0.34) of the difference in warming trends around the world's land masses. That is hardly the inconsequential effect asserted by the IPCC.

REWRITING HISTORY

If one can identify a non-climatic bias in temperature data, as we have done, then one can remove the bias and generate a more purely “climatic” set of warming trends. We endeavored to do so.

First, we made a few assumptions: rich countries with well-educated citizens take more reliable data, so we let every nation have the GDP density and educational attainment of the United States. We set the remaining socioeconomic variables to zero, allowing them no influence. Of course, we weighted the relative size of each geographic grid box in order to calculate a global result (far-north or -south boxes have much less area than those in the tropics).

When we factor out the socioeconomic effects, the 1979–2002 land warming trend becomes 0.13°C (0.23°F) per decade, compared to a weighted average of the UN's surface data of 0.27°C (0.49°F) per decade. That represents a drop of slightly over 50 percent. Because land is only 30 percent of the planetary surface, our results would lower the surface temperature trend by 50 percent times the land fraction (30 percent), or about 15 percent.

As shown in Figure 4, there are two distinct warming periods since 1900 — one that ran roughly from 1910 through 1945, and a second one that began around 1976. While there is a considerable interest in the lack of warming since the record global high in 1998, it is important to remember that two factors — the sun and El Niño — conspired to really hike the 1998 temperatures, and those factors are in a much different alignment now.

Most scientists still consider that the warming that began in 1976 has a strong “greenhouse” component because of its prevalence over cold, dry regions. (Antarctica is an exception to this; readers might want to consult *Cato Policy Analysis # 576*). Our study (1979–2002) is clearly applicable to this second warming, and lowers its rate (globally) from 0.17°C (0.31°F) per decade to 0.14°C (0.26°F) per decade.

One of the most interesting results of our research concerns the global distribution of the IPCC's surface temperatures after we adjust them for the non-climatic biases. Obviously the biases are different between nations. Very high biases of 0.5°C (0.9°F) per decade appear in southeast Asia, Africa, and South America, and a moderately high bias (of about 0.2°C (0.4°F)) is prevalent over western Europe. Data from the United States, most of the former Soviet Union, and the southern cone of South America show very little bias at all.

Adjustment for the non-climatic bias exerts a remarkable effect on the frequencies of the trends in the IPCC temperature data. Figure 5 gives the frequency distribution of observed trends in the IPCC data. The mean value is around 0.3°C (0.5°F) per decade, but the distribution has a very large right-hand “tail” of very warm readings — all the way to 1.0°C (1.8°F) per

Figure 6

Observed and Adjusted Global Temperatures

Data and trend lines

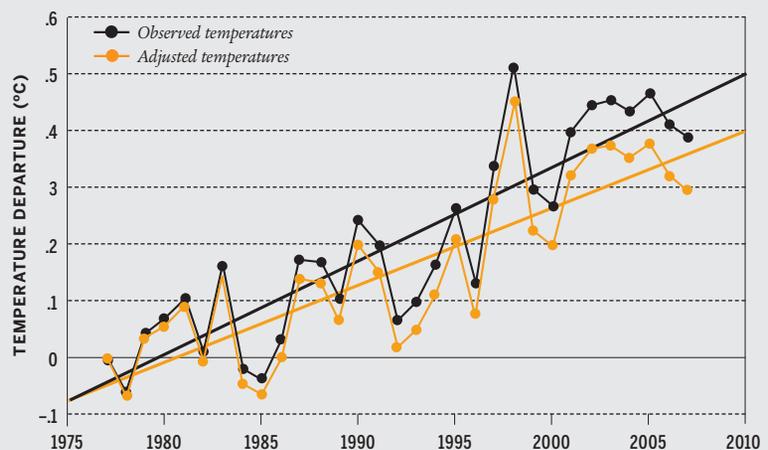
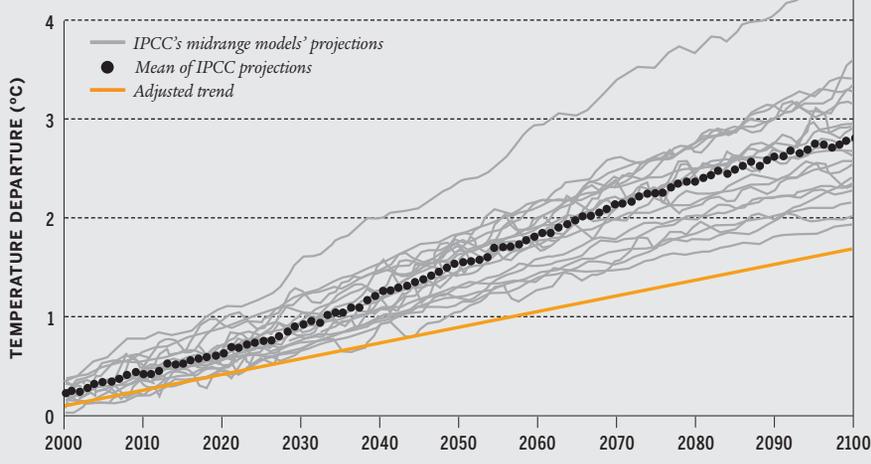


Figure 7

Adjusted Trend and the Midrange Models

IPCC midrange warming projections



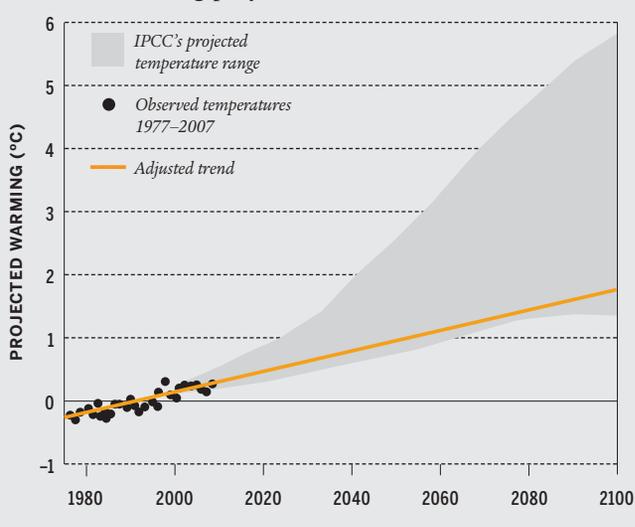
decade. The figure also gives the frequency distribution of trends in the satellite data, which presumably cannot suffer from socioeconomically induced bias. The average is around 0.23°C (0.41°F), or slightly less than the IPCC surface mean. The major difference between the two records is that there is no extreme right-hand (warm) tail. Adjusting the IPCC data for non-climatic bias (bottom chart) yields a frequency distribution that looks very much like the satellite data, which cannot suffer from socioeconomic bias. It seems fair to conclude that we have identified a very real, and heretofore undetected, bias in the IPCC's land surface temperature history.

Figure 6 gives the IPCC “observed” global temperature departures from the 1961–1990 averages. It also shows our adjustment for non-climatic biases since the second warming of the 20th century commenced in 1976. The result is a linear warm-

Figure 8

Adjusted Trend and All Models

All IPCC warming projections



ing rate of 1.4°C (2.5°F) per century.

Figure 7 displays multiple climate model outputs from the “midrange” carbon dioxide emissions scenario from the IPCC’s 2007 climate change compendium. These models project that, once greenhouse warming is initiated, it tends to take place at a constant (not an increasing) rate. On this figure, I have superimposed the “adjusted” warming trend, which is near the low end of all the models.

The IPCC produces a broader overall range of warming, using a much larger number of models and assumptions. That range is shown in Figure 8, with the adjusted surface data superimposed. The adjusted surface data also yields a warming that is almost exactly at the low end of the IPCC’s projected 21st century range.

CONCLUSION

Contrary to the assertions of the United Nations’ Intergovernmental Panel on Climate Change, there is a significant non-climatic warming in global land-surface temperature records. That warming results from previously unaccounted-for influences of non-climatic factors that are largely socioeconomic in origin. The result is that as much as half of the land-surface warming that has been detected in recent decades may be spurious. However, the quality factors noted above are not likely to have an effect on sea-surface temperature measurements, which apply to 70 percent of the surface. Consequently, the overall global warming trend since 1975 should be reduced by about 15 percent.

Mathematical simulations of climate tend to project a constant rate of warming, once warming from changes in greenhouse gases begins and is established. Indeed, the observed rate of warming (either with or without our adjustment) has tended to be constant. Our revised temperature record suggests that the warming of the 21st century will be around 1.4°C (2.5°F), which is at the extreme low end of the range of projections currently given by the IPCC. **R**

Readings

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- “Impacts of Urbanization and Land Use Change on Climate,” by E. Kalnay and M. Cai. *Nature*, Vol. 423 (2003).
- “Observations: Surface and Atmospheric Climate Change.” In *Climate Change 2007: The Physical Science Basis*. Intergovernmental Panel on Climate Change, 2007.
- “Precise Monitoring of Global Temperature Trends from Satellites,” by R. W. Spencer and J. Christy. *Science*, Vol. 247 (1990).
- “Quantifying the Influence of Anthropogenic Surface Processes and Inhomogeneities on Gridded Global Climate Data,” by R. R. McKittrick and P. J. Michaels. *Journal of Geophysical Research*, Vol. 112 (2007).