

Background Discussion On:

Quantifying the influence of anthropogenic surface processes and inhomogeneities on gridded global climate data

Ross R. McKittrick
Department of Economics
University of Guelph
Guelph ON Canada N1G 2W1
rmckitri@uoguelph.ca
519-824-4120 X52532

Patrick J. Michaels
Cato Institute
1000 Massachusetts Avenue NW
Washington DC 20001
pmichaels@cato.org

DECEMBER 2007

IN PRESS: JOURNAL OF GEOPHYSICAL RESEARCH-ATMOSPHERES

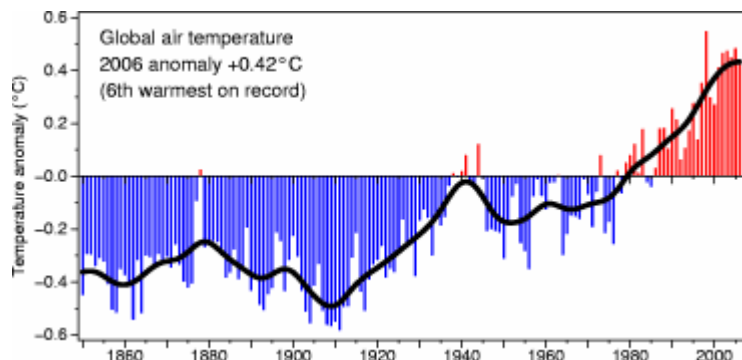
Paper, data and code available at

<http://www.uoguelph.ca/~rmckitri/research/jgr07/jgr07.html>

1. Sources of funding:

- Support for this research was received from the Social Sciences and Humanities Research Council of Canada.
- No industry funding of any kind was sought or received.
- McKittrick is a tenured Associate Professor at the University of Guelph. His Senior Fellowship at the Fraser Institute is an unpaid position, and was completely unrelated to this project.
- Michaels contributed to this research while a member of the Department of Environmental Sciences at the University of Virginia, and while a visiting lecturer at Virginia Tech.
- The data used in this paper were freely obtained from public sources.

2. Background



Source: <http://www.cru.uea.ac.uk/>.

This is the famous graph of “global average surface temperature,” or “global temperature” for short. The data come from thermometers around the world, but between the thermometer readings and the final, famous, warming ramp, there is a lot of statistical modeling aimed at removing known sources of exaggeration in the warming trend. In a new article just published in the *Journal of Geophysical Research-Atmospheres*, Pat Michaels and I have concluded that the manipulations for the steep post-1980 period are inadequate, and the above graph is an exaggeration, at least in the past few decades. Along the way I have also found that the UN agency promoting the global temperature graph has made false claims about the quality of their data.

The graph above comes from data collected in weather stations around the world. Other graphs come from weather satellites and from networks of weather balloons that monitor layers of the atmosphere. These other graphs didn't show as much warming as the weather station data, even though they measure at heights where there is supposed to be even more greenhouse gas-induced warming than at the surface. The discrepancy is especially clear in the tropics.

The surface-measured data has many well-known problems. Over the post-war era, equipment has changed, station sites have been moved, and the time of day at which the data are collected has changed. Many long-term weather records come from in or near cities, which have gotten warmer as they grow. Many poor countries have sparse weather station records, and few resources to ensure data quality. Fewer than one-third of the weather stations operating in the 1970s remain in operation. When the Soviet Union collapsed in the early 1990s, more than half the world's weather stations were closed in a four year span, which means that we can't really compare today's average to that from the 1980s.

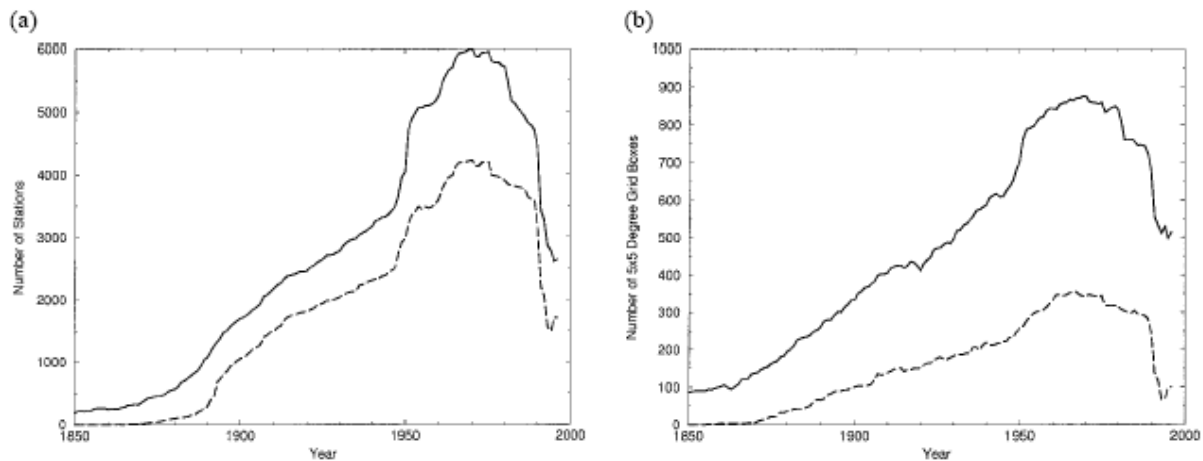


FIG. 2. Time series of the number of stations (a) and the number of $5^{\circ} \times 5^{\circ}$ boxes (b) for mean temperature (solid) and maximum and minimum temperature (dashed). The graphs start in 1850, but the earliest mean temperature datum is for January 1701 from Berlin, Germany, and the earliest mean maximum and minimum temperature data in GHCN are for March 1840 from Toronto, Canada. The reasons why the number of stations in GHCN drop off in recent years are because some of GHCN's source datasets are retroactive data compilations (e.g., World Weather Records) and other data sources were created or exchanged years ago. Only three data sources are available in near-real time. The rise in maximum and minimum temperature stations and grid boxes in 1995 and 1996 is due to the World Meteorological Organization's initiation of international exchange of monthly CLIMAT maximum and minimum temperature data over the Global Telecommunications System in November 1994.

Source: Peterson T.C. and R.S. Vose (1997), An overview of the Global Historical Climatology Network temperature database, *Bulletin of the American Meteorological Society* 78:2837—2849.

All these things can cause the temperature *data* to change, even if the Earth's climate doesn't. So how do we know the rate at which the climate is actually changing?

Scientists readily acknowledged that temperature measurements are contaminated for the purpose of measuring climate change. Warnings on the subject go back at least to the 1950s. But they argue that there are adjustments to fix the problem. To deal with a false warming generated by urbanization, they have the "Urbanization Adjustment." To deal with biases due to changing the time of day when temperatures are observed, they have the "Time of Observation Bias Adjustment." To deal with the loss of sampling coverage they have the "Coverage Adjustment." And so forth.

How do we know these adjustments are correct or adequate? In most studies the question is simply not asked. The reasoning is, in effect, we do not need to worry about urbanization bias because experts applied the Urbanization Adjustment. A few studies argue that the adjustments must be adequate since adjacent rural and urban samples give similar results. But closer inspection shows some of these papers don't actually give similar results at all, or when they do they define "rural" so broadly that it includes places that have at least partly urbanized, so the comparison is muddied. Other studies say the adjustments must be adequate because trends on windy nights look the same as trends on calm nights. But the long list of data problems includes issues that are just as serious under both windy and calm conditions.

The papers describing the adjustments aim to construct data showing what the temperature would be in a region if nobody had ever lived there. If the adjustments are right, the final output should not be correlated with the extent of industrial development and variations in socioeconomic conditions. That is something that can be tested. A few years ago Patrick Michaels and I first teamed up to look at how the pattern of warming over the Earth's land surface compared to local economic conditions. As expected, we found statistically significant correlations in weather station data, but we also found statistically significant correlations remained in the adjusted climate data—in other words, the adjustment models were not removing the contamination patterns as claimed. If the contamination were removed, we estimated the average measured warming rate over land would decline by about half. We published this study in 2004.

Unbeknownst to us, a pair of Dutch meteorologists, Jos de Laat and Ahilleas Maurellis, were also working on this topic. They used different data and a different testing methodology, but came to identical conclusions. In a pair of papers (published in 2004 and 2006) they showed several things. First, climate models predict there should be no correlation between the spatial pattern of warming in climate data and the spatial pattern of industrial development. But they found this correlation exists, and is statistically significant. They also concluded it adds a large upward bias to the measured global warming trend.

In response to some criticisms of my paper with Pat Michaels, I began working to assemble a more complete data base, covering all available land areas and a more extensive set of climatological and economic indicators. In the meantime, in 2005, I was asked to serve as an external reviewer for the IPCC Report, which was released earlier this year. I accepted, in part so I could make sure the data contamination problem was properly addressed.

Contamination of surface climate data is a potentially serious problem for the IPCC. Conclusions about the amount of global warming, and the role of greenhouse gases, are based on the assumption that the adjustment models work perfectly and there is no artificial warm bias in the climate records. Scientists who attribute warming to greenhouse gases argue that their climate models cannot reproduce the surface trends from natural variability alone. If they can't attribute it to natural variability, they attribute it to

greenhouse gases, since (they assume) all other human influences have been removed from the data by the adjustment models. If that has not happened, however, they cannot claim to be able to identify the role of greenhouse gases. Despite the vast number of studies involved, and the large number of contributors to the IPCC reports, the core message of the IPCC hinges on the assumption that their main surface climate data set is uncontaminated. And by the time they began writing the recent Fourth Assessment Report, they had before them a set of papers proving the data are contaminated.

How did they handle this issue? In the first draft of the IPCC Report, the problem was simply ignored with the claim that, while city data is distorted by urban warming, this does not affect the global averages. A couple of familiar studies were cited to support their position, but the new counter-evidence was ignored. I submitted lengthy comments criticizing this section.

In the second draft there was still no discussion, so again I put in lengthy comments.

This time the IPCC authors wrote a response, which is recorded in the review record for the IPCC AR4 (Chapter 3 Second Draft Review Comments, line 3-453). They conceded the evidence of contamination, but in a remarkable admission, said:

“The locations of socioeconomic development happen to have coincided with maximum warming, not for the reason given by McKittrick and Mihaels [sic] (2004) but because of the strengthening of the Arctic Oscillation and the greater sensitivity of land than ocean to greenhouse forcing owing to the smaller thermal capacity of land.”

Note the irony: confronted with published evidence of an anthropogenic (but non-greenhouse) explanation for warming, they dismissed it with an unproven conjecture that it can be chalked up to natural causes. Who’s the “denialist” now?

The claim is obviously preposterous. The comparison of land to ocean is irrelevant since we were only talking about land areas. The Arctic Oscillation is a wind circulation pattern that affects long term weather trends in the Arctic. It certainly plays a role in explaining Arctic warming over the past few decades. But for IPCC lead authors to invoke it as the explanation for a world-wide correlation between industrialization and warming patterns is nonsense, especially since de Laat and Maurellis had emphasized that climate models made no such prediction.

The final version of the report, published in May 2007, included the following paragraph (Chapter 3, page 244).

McKittrick and Michaels (2004) and De Laat and Maurellis (2006) attempted to demonstrate that geographical patterns of warming trends over land are strongly correlated with geographical patterns of industrial and socioeconomic development, implying that urbanisation and related land surface changes have caused much of the observed warming. However, the locations of greatest socioeconomic development are also those that have been most warmed by atmospheric circulation changes (Sections 3.2.2.7 and 3.6.4), which exhibit large-scale coherence. Hence, the correlation of warming with industrial and socioeconomic development ceases to be statistically significant. In addition, observed warming has been, and transient greenhouse-induced warming is expected to be, greater over land than over the oceans (Chapter 10), owing to the smaller thermal capacity of the land.

In the first sentence, the phrase “attempted to demonstrate” should be replaced with “showed.” This kind of slanted wording arises when organizations like the IPCC fail to control the biases of their lead authors.

The above paragraph acknowledges the correlation between warming trends and socioeconomic development. But it dismisses it as a mere coincidence, due to unspecified “atmospheric circulation changes.” The two cited Sections discuss some natural circulation patterns, but do not show that they overlap with the pattern of industrialization—the topic simply does not come up. And the de Laat and Maurellis paper effectively refuted such an explanation anyway.

The IPCC authors also claimed that, in view of the natural circulation changes “the correlation of warming with industrial and socioeconomic development ceases to be statistically significant.” Statistical significance is a precise scientific term, and a claim that results are insignificant requires specific numerical evidence. The IPCC evidently had none, but made the claim anyway. The technical term for this is “making stuff up.”

So there are two points to note here. First, they concede the existence of a correlation pattern that shows their main data set is contaminated, a criticism for which they have no coherent counterargument. Indeed their claim that it is due to natural circulation patterns contradicts their later (and prominently advertised) claims that recent warming patterns *cannot* be attributed to natural atmospheric circulation patterns.

Second, the claim that our evidence is statistically insignificant is, in my view, a plain fabrication by the IPCC. They cite no supporting evidence, nor is there any for them to cite. Confronted with two lines of independent evidence that the data set on which they base their fundamental conclusions is contaminated, they concede the point, but then dismiss it on the basis of fictional counter-evidence.

This is no mere tiff among dueling experts. The IPCC has a monopoly on scientific advising to governments concerning climate change. Governments who never think to conduct due diligence on IPCC reports send delegates to plenary meetings at which they formally “accept” the conclusions of IPCC reports. Thereafter they are unable—legally and politically—to dissent from its conclusions. In the years ahead, people around the world, including here in Canada, could bear costs of climate policies running to hundreds of billions of dollars, based on these conclusions. And the conclusions are based on data that the IPCC lead authors concede exhibits a contamination pattern that undermines their interpretation of it, and which they had to resort to making up counter-evidence to defend.

3. Structure and Findings of the New Paper

3.1 Data

Our 2007 paper presents a new, larger data set with a more complete set of socioeconomic indicators. We are interested in two types of contamination. The first arises because of what are called *anthropogenic surface processes*, i.e. any modification to the local landscape or atmosphere due to industrialization, urbanization, agriculture, etc. The second arises because of what are called *inhomogeneities*, i.e. discontinuities due to equipment changes, missing data, poor quality control, etc. To measure anthropogenic surface processes in each grid cell (a rectangle of land measuring 5 degrees by 5 degrees) we use the percent change, from 1980 to 2000, in population, real average income, real national Gross Domestic Product (GDP) and coal consumption. To measure inhomogeneities we use the 1979 real national GDP per square kilometer, the sum of literacy and post-secondary education rates and the number of missing months in the grid cell temperature record. We use GDP per square km as a measure of inhomogeneity since countries with low GDP density have a lot of land to monitor and relatively fewer resources available. We use education attainment not as a measure of the specific skills of individual staff, but to measure the general difficulty of recruiting skilled workers in an economy.

3.2 Model and Results

Our model takes the 1979-2002 warming trend in a grid cell and regresses it on three categories of variables: Climatic, Surface Processes and Inhomogeneities. Climatic variables include the warming trend in the lower troposphere just above the surface grid cell, mean air pressure, dryness, adjacent to coastline and latitude. The other two categories are described above.

We showed that the spatial pattern of warming trends is largely explained by the climatic variables. But it is also tightly correlated with indicators of economic activity. The probability that surface processes and inhomogeneities have no explanatory power for temperature trends is less than one in 14 trillion.

Are these fluke results? Is this a case of “spurious correlation?” We presented a battery of tests to rule out this possibility.

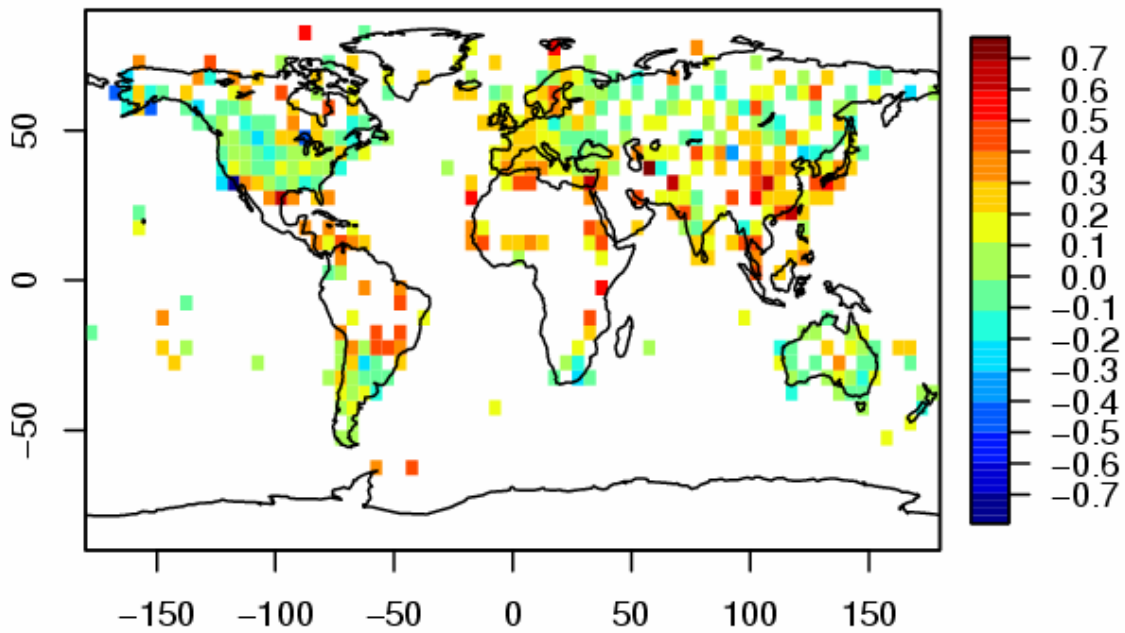
- Tests for the influence of outliers and nonlinearity did not show any effects.
- Multicollinearity diagnostics show that we do have sufficient explanatory power in the data to identify the effects.
- A Hausman consistency test shows that we are not picking up biases effects due to reverse causality.
- In 500 repetitions, we found that if we hold back 30% of the data set and estimate the model on the remaining 70%, the model then successfully predicts what the withheld 30% looks like.
- The correlations with surface processes and inhomogeneities that are significant in the surface data disappear when compared to data from the lower troposphere.
- Differences in effects arise when the sample is divided into economically growing and stagnating regions. The growing regions exhibit much stronger contamination patterns.

We conclude that these results cannot be dismissed as a meaningless fluke.

3.3 What if the Data Were ‘Clean’?

We can use the statistical model to estimate what the observed temperature trends would have been if everyone had as good circumstances for monitoring climate as the US does. The average trend at the surface in the post-1980 interval would fall from about 0.30 degrees (C) per decade to about 0.17 degrees. This shows that the problems identified in the statistical model add up to a net warming bias, and its removal could explain as much as half the recent warming over land.

The comparison between the IPCC data and the adjusted data as predicted by our model looks as follows.



Each square is colour-coded to indicate the size of the local bias. Blank areas indicate that there was no data available—a problem for interior Africa and South America.

To make a more precise estimate of the size of the contamination effects would require re-doing this study using a panel data format, which combines cross-sectional and time series information in a consistent estimation model. This is a direction for future research. (I do not plan to do it myself, but I would encourage someone to give it a try.)

Ross McKittrick

Guelph Ontario
December 3, 2007