

Letter to a Policymaker about Global Warming

By Ross McKittrick, Ph.D.

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INTRODUCTION

In September 2007 I was contacted by a politician in a western government (not Canada) studying the climate change file in preparation for cabinet-level decision-making. The request was phrased as follows: *“There's so much material and I have no hope of reading it all. My request is whether you might be able to identify half a dozen assumptions or hypotheses in the IPCC and related argument that global warming is upon us, is worsening, is caused by humans and will have severe consequences that, if any were wrong, would render these conclusions invalid.”* The politician did not claim strong prior views one way or the other.

What follows is a slightly edited version of what I sent in response. I have removed all identifiers of the person making the request. I have also added footnotes to sources and clarified some wording in one or two places.



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September 27, 2007

[recipient name and address snipped]

Dear [---]

In your email you asked me to address a half dozen of the most common assumptions behind the claims of the global warming crisis, that, if wrong, would invalidate the conclusions. Rather than send a pile of papers, I decided to compile a short write-up identifying the assumptions and sketching the counterarguments. For brevity I mostly skip providing citations, but I am happy to send source material on anything herein.

1. The Summary for Policy Makers (SPM) of the IPCC Report reflects the consensus of 2,500 of the world's top climate scientists.

This claim is untrue, simply because the participants in the IPCC process (whether they add up to 2,500 or not) are never asked whether they agree with the SPM conclusions.

I was an invited expert reviewer for Working Group I (which reviews the physical science). At no time was I asked whether I agree with the SPM, since it did not appear until 7 months after the end of the review process. Neither were any other expert reviewers or contributing authors surveyed, and, knowing who many of them are, I am sure that they disagree with many IPCC conclusions. Having read many of the review comments (which are now posted online¹) it is clear that the IPCC received heavy criticism on many aspects of its report, especially those that affected the high-profile conclusions that would be included in the SPM. But the IPCC Lead Authors—a small circle of people who share a known point of view, who are hand-picked by the IPCC Bureau—simply dismissed and ignored comments that challenged their position, even when those comments were fully rooted in published peer-reviewed literature.

As with all other reviewers, my final comments were submitted by June 2006, responding to the Second Order Draft of April 2006. After that, the IPCC accepted no further input from reviewers. The next draft was finished in October 2006,² but was not released for review. The SPM was negotiated in Paris in January 2007, and only about 30 scientists were involved; the rest were

¹ <http://ipcc-wg1.ucar.edu/wg1/Comments/wg1-commentFrameset.html>

² <http://www.ipcc.ch/meetings/calendar.htm>

government negotiators. A further revision to the full report was then done (without review) by the IPCC, to bring the text into agreement with the SPM. This version was published in May 2007.

There were some telling changes between the Second Order Draft and the final draft. For example, a section I worked on in detail (Ch. 3.2.2.1) looked at the problem of evaluating the significance of trends in climate data, i.e. determining if a trend is larger than can be accounted for by natural variation. The conclusion of that section, as of April 2006, read

Determining the statistical significance of a trend line in geophysical data is difficult, and many oversimplified techniques will tend to overstate the significance. Zheng and Basher (1999), Cohn and Lins (2005) and others have used time series methods to show that failure to properly treat the pervasive forms of long-term persistence and autocorrelation in trend residuals can make erroneous detection of trends a typical outcome in climatic data analysis.

This view is well-established in the technical literature and there were no objections to it by reviewers. Yet the above paragraph was deleted from the final, published Report. There are other examples like this.

When I finished my review of the Second Draft of the IPCC Report, the overall impression I had was that much of the Report was quite good: balanced, well-written and fair. It was quite honest about the uncertainties and difficulties in climate science. But there were a few sections where the tone changed, becoming brittle, one-sided and tendentious. These sections covered paleoclimate reconstructions (i.e. the hockey stick), “signal detection” (modeling work that tests whether GHG’s drive modern climate change) and surface temperature measurement. These are topics that tend to dominate the SPM.

Anticipating that the SPM would not properly convey the real contents of the report, I assembled a team of scientists in 2006 to read the IPCC Second Draft and write an Independent Summary for Policy Makers (ISPM). Our paper was published by the Fraser Institute. We received no industry funding and had total editorial control the whole way through. We provided a detailed guide to the material in the IPCC report, on the basis of which we concluded that “There is no compelling evidence that dangerous or unprecedented changes are underway.” We sent the ISPM to a hundred reviewers, receiving input from about 60. We surveyed our reviewers to gauge their support for the ISPM and posted the results on-line (<http://www.uoguelph.ca/~rmckitri/research/ispm.html>). I believe our ISPM is far superior to the IPCC’s. The survey responses are as follows:

1. To what extent does the ISPM cover the range of topics you consider important for policy makers and other general readers who want to understand climate change?

- 1 (Quite Inadequately)
- 2 (Somewhat Inadequately)
- 3 (Neutral)
- 4 (Adequately) Mean response = 4.2**
- 5 (Quite Adequately)

2. To what extent do you consider the ISPM to convey the current uncertainties associated with the science of climate change?

- 1 (Generally overstates the uncertainties)
- 2 (In some cases overstates the uncertainties)
- 3 (Is about right) Mean response = 3.3**
- 4 (In some cases understates the uncertainties)

5 (Generally understates the uncertainties)

3. To what extent to you agree with the Overall Conclusions?

1 (Strongly disagree)

2 (Disagree)

3 (Neutral)

4 (Agree) Mean response = 4.4

5 (Strongly Agree)

4. Do you support the publication of the ISPM as a means of communicating the current state of climate science to policy makers and other general readers?

1 (No, strongly opposed)

2 (No, somewhat opposed)

3 (Neutral)

4 (Yes, somewhat in support)

5 (Yes, strongly in support) Mean response = 4.7

Implications

From your perspective as a policy maker, what are you make of the claims of “consensus”? It is simple: we would all like to know what the world’s scientists, taken as a group, think about some key questions on global warming and greenhouse gases. So why won’t anyone survey them? A few years ago a pair of German climatologists surveyed 530 climate modelers and asked them whether they thought human GHG’s were mostly responsible for climate change. Only 34% Agreed or Strongly Agreed; more than 20% Disagreed or Strongly Disagreed, the rest were in the middle. They concluded that it is doubtful the majority of climatologists agree with the IPCC. The scientist (Bray and von Storch) submitted their paper as a comment to *Science*, who refused to publish it.

Those who rest their beliefs on the claim of consensus ought to welcome a survey. I would suggest having a professional pollster survey tens of thousands of scientists around the world on a variety of questions pertaining to the science. I am sure any such survey will reveal deep scientific divisions on what remains a very complex and difficult research subject.

2. Simple physics proves that greenhouse gases cause global warming, just like in a real greenhouse.

In 2002 I coauthored the book *Taken By Storm: The Troubled Science, Policy and Politics of Global Warming* with Christopher Essex, a physicist and long-time climate modeling expert. We discussed at some length why this claim is incorrect. It widely-known among scientists to be incorrect, but the public misconception is very hard to shake.

What greenhouses do is uncomplicated. If the greenhouse metaphor were correct, there would be no need to develop large-scale computer models to determine what the atmosphere and oceans will do, and weather would be easy to predict.

The Earth’s energy balance requires that energy flows from the sun to the surface must be balanced by energy flows from the surface back to space. About half the energy at the surface leaves through infrared radiation, and the other half is removed by the fluid dynamics of the atmosphere: convection, turbulence, wind, evaporation, and so forth.

In a greenhouse, movement of air is diminished, so the radiative portion of the energy drain must intensify. Physics can predict with certainty that in order to increase outbound radiation from a greenhouse, temperature inside the greenhouse must increase. A greenhouse must warm up.

But the story in the atmosphere is different. We are adding small amounts of infrared-absorbing gases (like carbon dioxide) to the atmosphere. This does not “trap heat” as the saying goes, instead it diminishes the efficiency of the radiation drain. So the fluid dynamics must adjust to maintain energy flow balance. In order to predict what will happen at the Earth’s surface, it is necessary to solve the equations governing fluid dynamics.

The problem is that no one knows how to do it. The equations governing fluid motions, including basic atmospheric and climate processes, are called the Navier-Stokes equations. These equations are famous among scientists for being too difficult to solve directly. This means they cannot be used for direct computation. There is a standing offer of \$1 million (US) from the Clay Mathematics Institute (http://www.claymath.org/millennium/Navier-Stokes_Equations/) for anyone who can simply prove that a solution to the Navier-Stokes equations exists. There is no “simple physics” here. People who claim to be able to prove, by simple physics, that CO₂ must warm the Earth’s atmosphere at the surface, are saying they have solved the fluid dynamics problem. They should contact the Clay Institute to claim their prize. So far nobody has.

Computer climate models use empirical approximations in lieu of the (unavailable) theory. The standard empirical approximation these days supposes that there is an “effective emissions altitude” from which the infrared radiation emerges that goes out to space, and this emissions altitude must rise as CO₂ levels rise.³ Since the radiation emerges from a higher, and thus cooler, part of the atmosphere, the temperature must rise, and this starts the whole warming process.

These models are valuable, but it is not known among modelers that they are “right.” A recent review of the state of climate modeling noted the fact that models are calling for an acceleration of tropospheric warming in the tropics (primarily due to water vapour accumulation), which has not been observed. They conclude:

Given the acceleration of trends predicted by many models, we believe that an additional 10 years may be adequate, and 20 years will very likely be sufficient, for the combined satellite and radiosonde network to convincingly confirm or refute the predictions of increasing vapor in the free troposphere and its effects on global warming.

(Held, I. and B. J. Soden (2000) “Water Vapor Feedback and Global Warming” *Annual Review of Energy and Environment* 25:441—75, page 471.)

The point to take away is simply that these authors, and their colleagues, know the limits of the tools they are working with. The available data does not suffice to confirm the validity of current models, and new data expected in the years ahead may refute them.

Implications

From your perspective as a policymaker, you need to bear in mind that climate models are not reliable enough as forecasting tools to provide a basis for costly policy gambles. Policy commitments should remain flexible and revisable as new data and new understanding comes to light. There needs to be a robust feedback between the stringency of any policy and the observed progress of climate, so

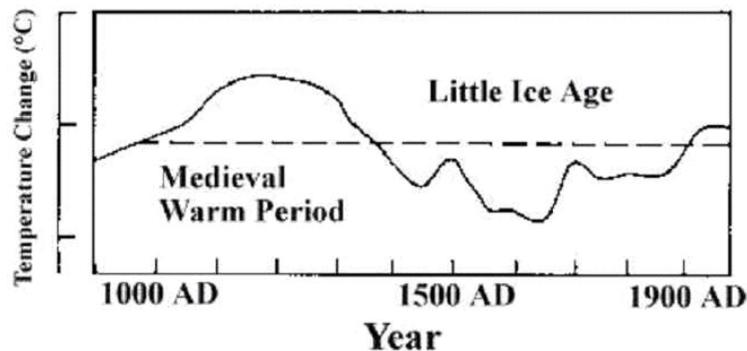
³ For an exposition see Held, I. and B. J. Soden (2000) “Water Vapor Feedback and Global Warming” *Annual Review of Energy and Environment* 25:441—75.

that if the problem turns out to be more *or less* serious than initially proposed, policy can adjust accordingly.

3. The global average temperature over the 20th century has risen outside natural bounds.

I have many objections to this statement, of which I will discuss four. First, the IPCC promoted a false “hockey stick” view of minimal natural variability, that has been discredited. Second, modern surface temperature data overstates warming. Third, despite some claims to the contrary, weather satellite data still do not support the rate of change in surface data. Fourth, IPCC statistical methods underestimate the natural component of trends.

3.1 In its 1990 report,⁴ the IPCC presented the following picture as a summary of the then-standard view of the variability of Earth’s average temperature for the past 1100 years, showing that 20th century climate changes were not unusual in historical context:

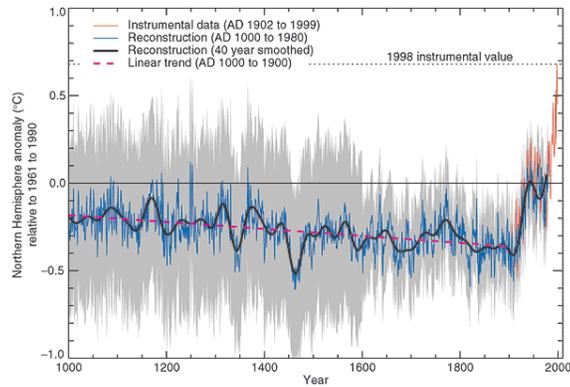


In the 1995 IPCC Report, they did not revise this picture. As late as 1997, climatologists were still using this picture as the consensus view of the field, based on a huge body of evidence pointing to warmer conditions in the medieval era than at present.

The publication of the hockey stick graph in 1998⁵ (and its extension in 1999) portrayed climate history in a radically different light. It suggested historical variability in Northern Hemisphere (and likely global) temperature is quite small, and recent climate change goes far outside those bounds.

⁴ Figure 7.1 in the First Assessment Report of the Intergovernmental Panel on Climate Change (1990).

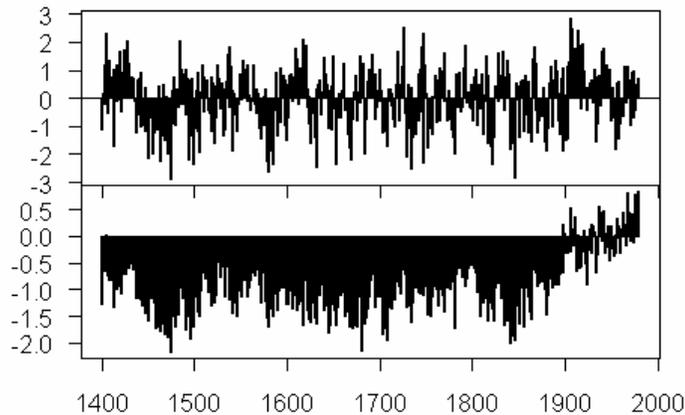
⁵ Mann, M.E., Bradley, R.S. and Hughes, M.K., 1998. Global-Scale Temperature Patterns and Climate Forcing Over the Past Six Centuries, *Nature*, 392, 779-787; Mann, M.E., Bradley, R.S. and Hughes, M.K., Northern Hemisphere Temperatures During the Past Millennium: Inferences, Uncertainties, and Limitations, *Geophysical Research Letters*, 26, 759-762, 1999.



Despite the fact that the author, Michael Mann, was a new Ph.D., publishing an outlier result based on a new methodology that nobody understood, the IPCC invited him to write the survey of paleoclimatology for the Third Assessment Report, and allowed him to focus exclusively on his own findings, over the stated objections of other authors.⁶ As indicated in item #1 above, what we are learning about the IPCC process gives good reason for responsible policy makers to look with great caution upon the work of the IPCC after 2001.

Not until six years after its publication did the hockey stick get an independent examination, when my colleague Steve McIntyre obtained Mann's data set and attempted to replicate the result. As is now well known, we eventually found errors that undermined all the main conclusions.

A good illustration of the problem is to compare the simple average of all the 415 temperature proxies (mostly tree ring records) in Mann's 1998 data set⁷ (which runs from 1400 to the present) to the final result.



*Top – Simple average of 415 proxy series in Mann's data set.
Bottom – hockey stick reconstruction.*

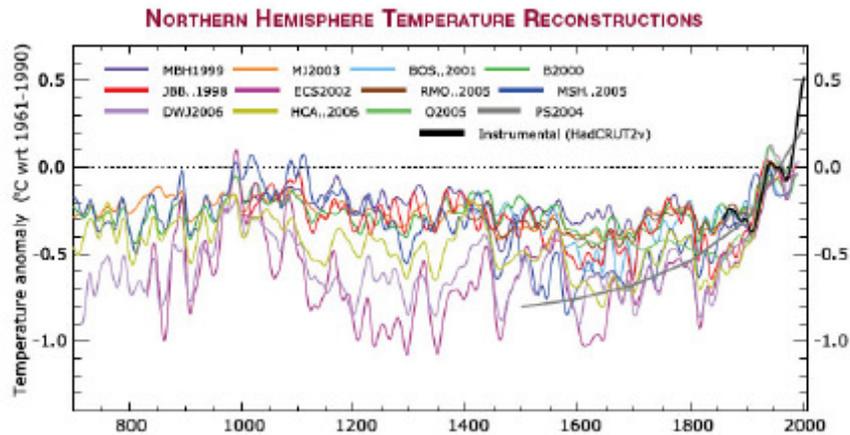
The simple average of temperature proxy measures around the world shows no trend, and indeed slopes down in the 20th century. After Mann's black-box statistical processing, the result shows a dramatic ramp up after 1850, peaking in 1980 (the thermometer data extrapolates to 1998 in the

⁶ This was communicated to me in a personal conversation with another IPCC author.

⁷ Data: <http://www.nature.com/nature/journal/v430/n6995/extref/nature02478-s1.htm>. Calculations: S. McIntyre.

published version). The striking hockey stick shape is entirely an artifact of the averaging method, and in particular traces to a faulty step that loads far too much weight on a small number of bristlecone pine series from western USA, which have long been believed to be indicators of atmospheric CO₂ levels, not local temperature. The 2006 National Academy of Science panel investigating this issue concluded that these bristlecone series should not be used in paleoclimate reconstructions.⁸ If they are removed from Mann's data base then there is no hockey stick left, regardless of how the graph is put together.

In our analysis, McIntyre and I also showed that there is no statistically-significant connection between Mann's proxy data and his temperature data, so extrapolating forward using modern thermometer records is invalid.⁹ This is a more general result: no one has passed the statistical tests needed to establish that modern globally-averaged temperature data is an extrapolation of globally-averaged historical proxy data. Recent updates to proxy records show that tree ring widths around the world are have been declining since 1980, which, if they are supposed to be a measure of temperature, implies we are experiencing global cooling. More likely it means that trees are lousy thermometers.¹⁰ The National Academy of Sciences agreed with us that the relationship between global instrumental (thermometer) records and global tree ring proxies is insignificant,¹¹ yet in the 4th Assessment Report the IPCC spliced the two together (over reviewer objections).



From the IPCC 2007 Report.

If you look closely you'll see that without the heavy black line at the end, which shows the instrumental (thermometer) data, the graph just shows a lot of noise, rather than a dramatic hockey stick shape. I wrote a detailed critique of the splice in this graph in my IPCC review, citing the

⁸ National Research Council (2006) *Surface Temperature Reconstructions for the Last 2,000 Years* Washington: National Academies Press, p. 50.

⁹ McIntyre, Stephen and Ross McKittrick (2005) Hockey Sticks, Principal Components and Spurious Significance *Geophysical Research Letters* Vol. 32, No. 3, L03710 10.1029/2004GL021750 12 February 2005

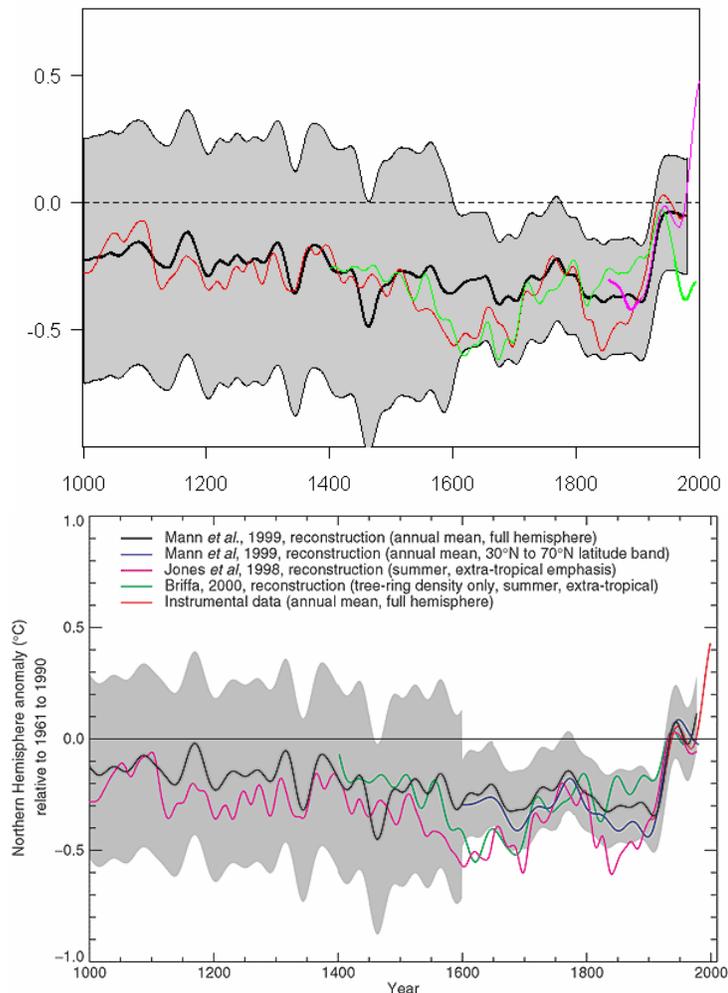
¹⁰ See K. R. Briffa, F. H. Schweingruber, P. D. Jones, T. J. Osborn, I. C. Harris, S. G. Shiyatov, E. A. Vaganov and H. Grudd, 1998. *Phil.Trans. R. Soc. Lond. B* (1998) 353, 65-73; also see <http://www.climateaudit.org/?cat=64> for discussions.

¹¹ NRC Report pp. 91, 107.

relevant literature. Even though they acknowledged the point, they elected to leave the black line in and simply note in the text that it is not valid to extrapolate.

A couple of other comments about that graph. The lines all converge in the 1850-1950 interval because they are constrained to. They fan out before and after, indicating their lack of overall coherence. If they had been constrained to agree in, say, the 1400s, they would spread out widely across the whole 20th century. All the strands that look like hockey sticks re-use Mann's bristlecone data, and if you remove the bristlecones (as recommended by the National Academy of Science) their hockey stick shape disappears. Some even continue to use his faulty averaging method, even after it was condemned by the National Academy panel.

In the post-1960 segment, one of the reconstructions drops quickly after 1960, but the IPCC decided it would be "inappropriate" to show this, so they deleted it, over explicit reviewer objections. They did this in both the 2001 and 2007 reports.

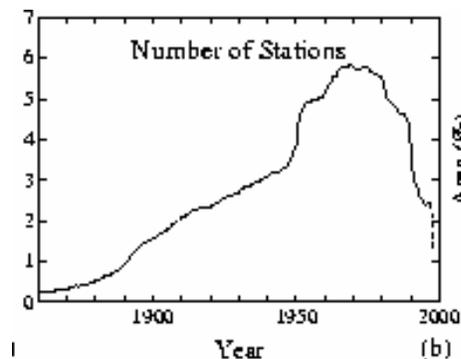


Top: What the full data series from the underlying papers look like.

Bottom: As shown in the IPCC (2001) Report after deleting the end portion of the green line. Note the pink line is the instrumental data spliced in.

<http://www.climateaudit.org/?p=1579>

3.2 Looking at the 20th century thermometer record, the following graph, taken from the NASA website (http://data.giss.nasa.gov/gistemp/station_data/)¹² illustrates a basic measurement problem. The graph shows the number of weather stations around the world from 1850 to 1997.



The total number of continuous temperature measurement stations around the world in the Global Historical Climatology Network rose to a peak of over 6,000 in the 1970s, but since then has fallen to about 2,000, with a sudden drop in the early 1990s coinciding with the collapse of the Soviet Union. During that interval the sample was cut in half from about 5,000 to about 2,500 stations. There is simply no continuous 20th century climate data for large regions of the world, including Africa, South America, the Middle East and large sections of Northern Asia.

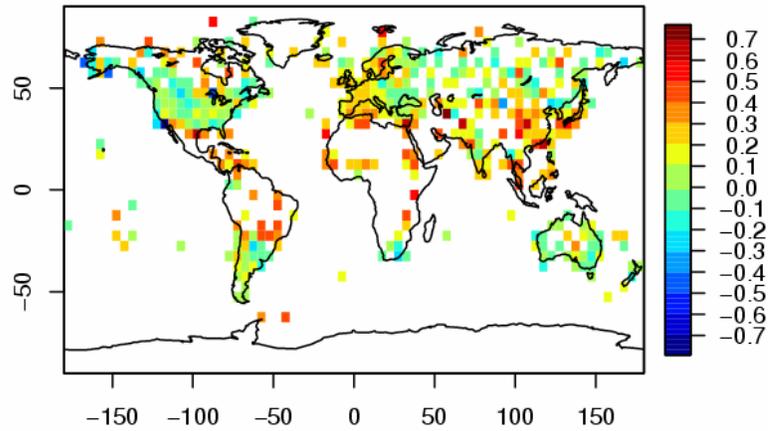
Where temperature data do exist, they are collected for weather monitoring purposes, not for climate measurement. Climate measurement is supposed to tell us what the air temperature would have been over time in a location if humans had never arrived there and if no changes to the land surface had ever occurred. Since we obviously can't measure that, models are used to conjecture what such data would show. What we actually see in graphs of climate data are the outputs of models, in which weather data is only one of several inputs, along with population data, ad hoc adjustment coefficients, etc.

The IPCC (and its contributing authors) claim that these adjustments remove all traces of non-climatic signals related to industrial activity and anthropogenic changes to the land surface. In 2004 I published¹³ a study in *Climate Research* in which my coauthor and I conducted the first formal statistical test of this claim. Of course it failed by a large margin. We also showed that the residual biases add up to a large net warming bias. Other, similar results were also published in the literature around this time by several other teams working independently. We have just had another paper accepted¹⁴ in *Journal of Geophysical Research* which shows that the probability that the IPCC successfully removed all the non-climatic biases from their data is 0.000000000071%. In line with other studies we estimate that half the post-1980 warming trend in surface temperature data can be explained as contamination of the basic data due to land-surface changes. The spatial pattern of bias is as follows (colours denote °C/decade):

¹² The original source is Peterson TC, Vose RS (1997) An overview of the global historical climatology network temperature database. *Bull Am Meteor Soc* 78:2837—2849.

¹³ McKittrick, Ross and Patrick J. Michaels (2004). "A Test of Corrections for Extraneous Signals in Gridded Surface Temperature Data" *Climate Research* 26 pp. 159-173.

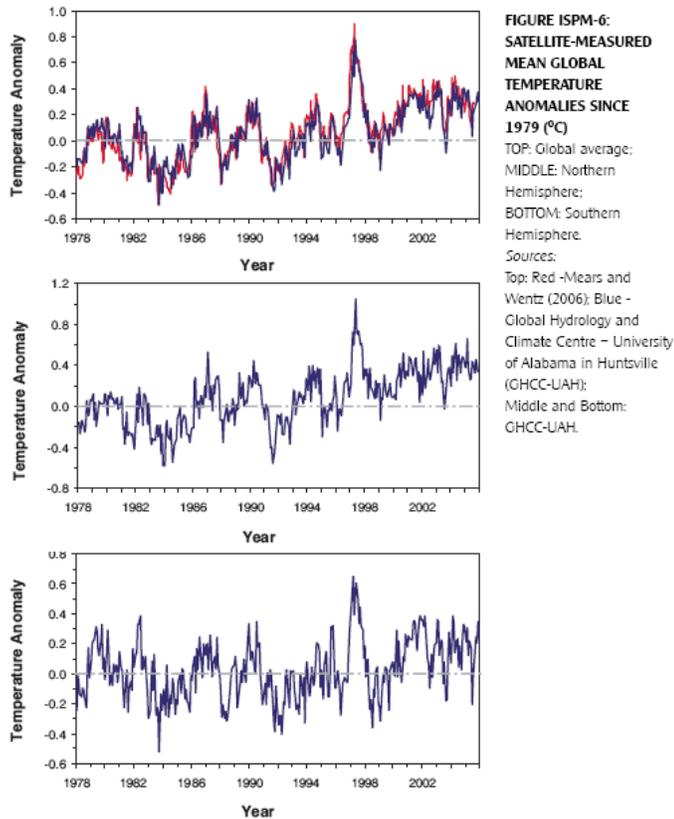
¹⁴ McKittrick, R.R. and P.J. Michaels (2007), Quantifying the influence of anthropogenic surface processes and inhomogeneities on gridded global climate data, *J. Geophys. Res.*, 112, D24S09, doi:10.1029/2007JD008465.



The blank areas indicate where there is insufficient post-1980 temperature data to establish a trend.

The IPCC's treatment of this data quality topic in the Fourth Assessment Report was biased and inadequate. There were only a few reviewers who commented on the topic, but some chided the IPCC for failing to address the topic properly. The IPCC's dismissal of these complaints was very problematic.

3.3 In the post-1980 interval there is no need to rely on the faulty surface temperature data network, since we have good quality weather satellites that sample in the lower atmosphere (the troposphere) where climate models predict there ought to be greater warming than at the surface. But the weather satellites indicate less warming in the troposphere than at the surface. The record is as follows (from the ISPM Figure 6)



Satellite data has been subject to extreme scrutiny and controversy (little scrutiny, by comparison, has been applied to surface data). In the Summer of 2006 the US Climate Change Science Program (CCSP) released a big report¹⁵ on its attempt to reconcile the surface and satellite data. The opening paragraph of the Executive Summary reads (emphasis added):

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.**

The media ran with this claim and the IPCC repeated it in their SPM, as it seemed to suggest that satellite data now show more warming than the surface data. But this is not true, as the CCSP report pointed out on the next page.

For observations during the satellite era (1979 onwards), the most recent versions of all available data sets show that both the low and mid troposphere have warmed. **The majority of these data sets show warming at the surface that is greater than in the troposphere**

¹⁵ Available at <http://www.climatechange.gov/Library/sap/sap1-1/finalreport/default.htm>.

[In the tropics] Although **the majority of observational data sets show more warming at the surface than in the troposphere**, some observational data sets show the opposite behavior. **Almost all model simulations show more warming in the troposphere than at the surface.** This difference between models and observations may arise from errors that are common to all models, from errors in the observational data sets, or from a combination of these factors. The second explanation is favored, but the issue is still open.

Even this understates the fundamental disagreement between the observational data sets and the model projections. At the end of the Summary they make the following very telling admission (CCSP Report page 11):

For global averages (Fig. 3), models and observations generally show overlapping rectangles. A potentially serious inconsistency, however, has been identified in the tropics. Figure 4G shows that the lower troposphere warms more rapidly than the surface in almost all model simulations, while, in the majority of observed data sets, the surface has warmed more rapidly than the lower troposphere. In fact, the nature of this discrepancy is not fully captured in Fig. 4G as **the models that show best agreement with the observations are those that have the lowest (and probably unrealistic) amounts of warming.**

Many lead authors of this report were also lead authors for the IPCC. It is a remarkable window into their mindset to note that the models they deem “probably unrealistic” are the ones that best fit the data, but depart the most from the authors’ prior expectations.

3.4 I mentioned above the removal of a paragraph from the IPCC Report concerning the tendency for false trend detection in geophysical data. The issue is referred to in the literature as Long Term Persistence. One recent paper on this topic by Cohn and Lins¹⁶ (*Geophysical Research Letters* 2005) concludes:

“[With respect to] temperature data, there is overwhelming evidence that the planet has warmed during the past century. But could this warming be due to natural dynamics? Given what we know about the complexity, long-term persistence and non-linearity of the climate system, it seems the answer might be yes...natural climatic excursions may be much larger than we imagine.”

The IPCC relies on primitive statistical analysis methods that are known to underestimate natural variance, and overestimate the statistical significance of trends. Modern methods of time series analysis, of the sort common in finance and econometrics, give very different answers to the kinds of estimations the IPCC does. Although in the first drafts of the IPCC report they introduced a small treatment of the topic, in the final draft they deleted it.

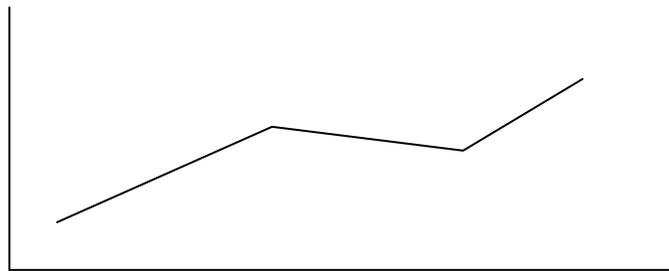
Implications

From your perspective as a policymaker, you would never allow economists to cobble together a Consumer Price Index with as many problems as the global average temperature index. There are serious quality control problems that likely cause it to overstate global warming, and make it hard to assess whether the climate exhibits behaviour that falls outside natural variability.

¹⁶ Cohn, T.A. and H.F. Lins, 2005: Nature's style: Naturally trendy. *Geoph. Res. Lett.*, **32**, L32402, doi:10.1029/2005GL024476.

4. Climate models cannot explain 20th century warming by natural variability alone, but only when a strong warming effect of CO₂ is included.

The studies in question are trying to explain an upward trend in a temperature statistic over the 20th century, where a flat interruption occurs mid-century.



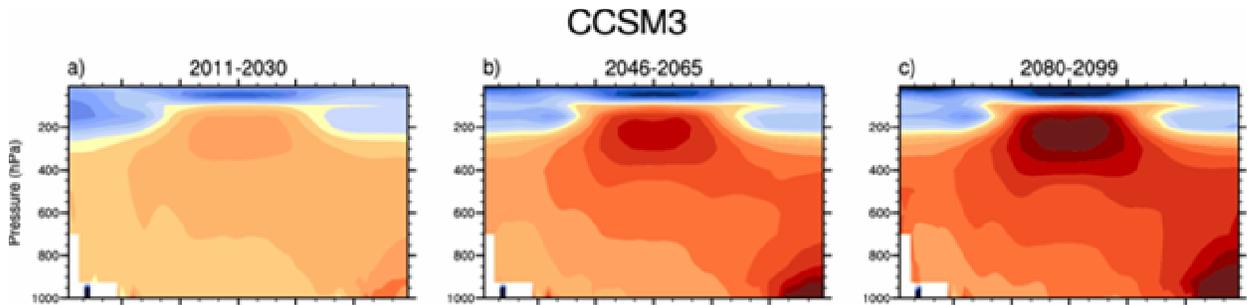
An equation with three free parameters can fit this graph, but that does not mean such a model “explains” it.

The IPCC argument against natural explanations only considers effects due to solar fluctuations and volcanic eruptions, and assumes that, without these, the climate would otherwise be flat and unchanged. Further, the influence of the sun is assumed to be very small, with no indirect effects on cloud formation, and volcanic eruptions have only short term effects. These model runs do not, indeed, fit the above profile. *Ergo*, the argument goes, 20th century climate change cannot be explained by natural factors. Then the modelers program in a strong CO₂-warming effect and a strong aerosol cooling effect, and assume that aerosol levels were high in mid-century then tapered off after 1960 (despite having no reliable data on this for most countries). The above shape emerges, *ergo* etc.

But the IPCC’s signal detection study do not control for the effects of: contamination of the surface data due to large-scale land-use change and the loss of most monitoring stations after 1975 (when the above line starts sloping up); chaotic interactions of large-scale pressure oscillations like the Pacific Decadal Oscillation, Arctic Oscillation and North Atlantic Oscillation; or indirect solar effects on cloud formation; to name a few. Dick Lindzen calls the IPCC argument “Proof by Lassitude”: we couldn’t explain it using some simplistic natural processes after a few minutes of trying one or two of them, so we gave up and chalked it up to CO₂ emissions.

Also missing from this argument is recognition of the failure of models with a strong CO₂ effect to match the vertical profile in the atmosphere. All 12 model runs for the recent IPCC Report (Figure 10.7) show a strong warming concentrated in the tropical troposphere.¹⁷

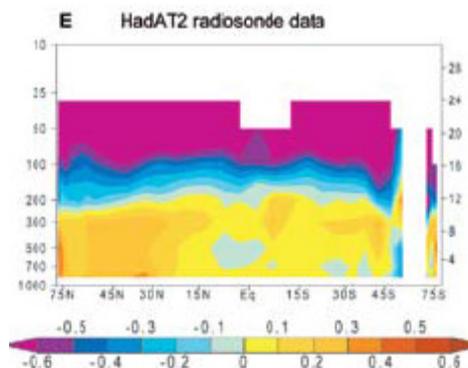
¹⁷ http://ipcc-wg1.ucar.edu/wg1/Report/suppl/Ch10/Ch10_indiv-maps.html



In each of these three panels, the horizontal axis shows latitude (left to right = South Pole to North Pole) and the vertical axis shows altitude, measured in atmospheric pressure, corresponding to about 25 km total height. The colour denotes the intensity of the warming trend. The 3 panels refer to 3 time intervals; in Figure 9.1 the IPCC generates a very similar profile as its prediction of what ought already to be observed in 20th century data.

The big red boil in the top middle is the tropical troposphere. In all model runs, this is where the warming starts and runs strongest. Models also indicate that this pattern is uniquely associated with greenhouse gas (GHG) effects. Amplified warming at the North Pole is associated with GHG emissions but is also associated with solar changes. The amplified warming over the tropics is only associated with greenhouse gases.

This is why the US Climate Change Science Program drew so much attention to the tropics (bear in mind the tropics make up half the global atmosphere). In none of the available data sets, from satellites or weather balloons, is there amplified warming over the tropics. At the back of the CCSP report (p. 116) they showed the weather balloon data, which closely matches the satellite data (which they didn't show):



The mismatch in the tropics is clear: it is cooling at the lower level, and the warming at the mid-level is less than in adjacent areas outside the tropics. Models run with a strong CO₂ warming cannot reproduce this pattern.

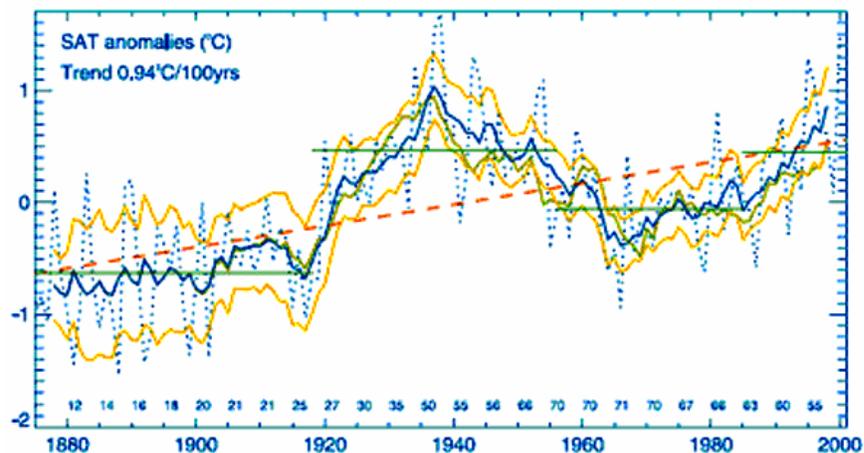
Implications

From your perspective as a policymaker, you should be cautious when people point to this or that weather event as a sign of GHG-induced global warming. The weather is always changing, and the climate is always variable. The IPCC tells us that the one clear signal of GHG-induced global

warming will be in the tropical troposphere. That is what we should measure in order to gauge the severity of GHG-induced climate effects. There is good data available from weather satellites and weather balloons for this region of the atmosphere, and so far they do not indicate a warming trend of the kind predicted by climate models.

5. The Arctic is melting at unprecedented rates.

Today's Arctic climate conditions appear to be similar to those in the 1930s. The 2002 Arctic Climate Impact Assessment (ACIA)¹⁸ was prepared by a list of authors with considerable overlap with the IPCC. They claimed that Arctic average temperatures were at an all-time high. But the most comprehensive published survey of Arctic average temperatures at the time (Polyakov et al., 2002)¹⁹ showed that the 1930s were just as warm. The ACIA ignored this study.



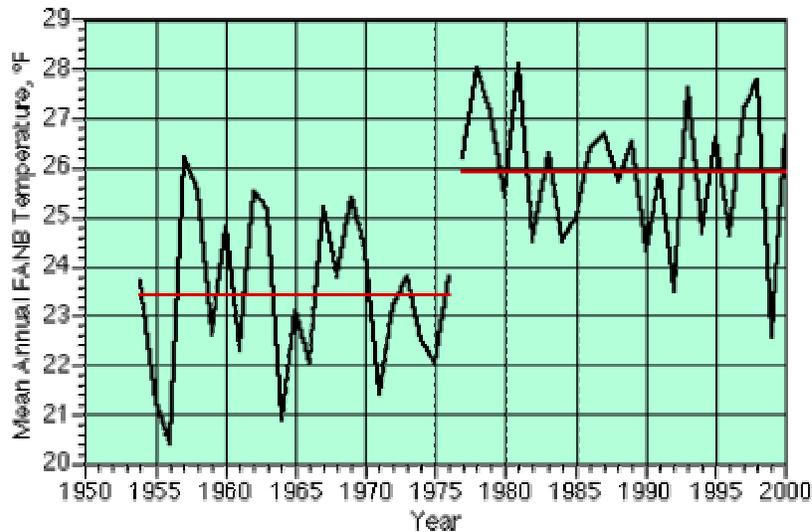
From Polyakov, I., et al., 2002. Trends and Variations in Arctic Climate Systems. *Eos, Transactions, American Geophysical Union*, 83, 547-548.

The ACIA did not use this record, or any other published record, instead they made up their own data series which was based on a non-standard definition of the boundary of the Arctic that included some regions of Siberia with very poor quality temperature records, which showed large upward trends.

Still, there have been indications of warming in the western Arctic and around Alaska. However almost all the changes in this region happened in a 2-year span in 1977-78, during an event called the Pacific Climate Shift.

¹⁸ <http://www.acia.uaf.edu/>

¹⁹ Polyakov, I., et al. (2002) .Trends and Variations in Arctic Climate Systems. *Eos, Transactions American Geophysical Union*, 83, 547548.293(15) 1861.1867.



Mean annual temperature in Fairbanks, Anchorage, Nome and Barrow Alaska
(From <http://climate.gi.alaska.edu/Bowling/FANB.html>)

The Arctic is strongly affected by some high-latitude pressure oscillations, chiefly the Arctic Oscillation, the Atlantic Multi-Decadal Oscillation (AMO) and the Pacific Decadal Oscillation (PDO). The IPCC Report discusses each of them. Scientists have only just worked out reliable measurements of them, and are just beginning to understand how they create regional temperature cycles on time scales of 30-60 years or so. The PDO flipped modes in 1977, an event called the Pacific Climate Shift, which led to an abrupt warming around the north Pacific and Arctic around Alaska. The AMO also changed modes in the 1990s into a system that favours wintertime “blocking” events that leads to warmer winter air over North America. It also pushed warm Atlantic currents into the Arctic, which appears to have been a factor behind sea ice thinning. The Arctic Oscillation intensified in the late 1980s, putting all three systems into a mode that favours northern and Arctic warming since the 1990s. Data exist to support the view that these oscillation systems are primarily driven by solar fluctuations, though the IPCC also suggests they are driven by ocean currents. There is some evidence that both the AMO and PDO are once again changing modes.²⁰

As for sea ice coverage, reference is often made to the satellite record, which only goes back to 1978. This year’s summer melt took ice cover to its smallest extent since 1978. However, regional records going back to the 1700s (Baltic Sea)²¹ and 1529 (Latvia)²² show long intervals in past centuries during which sea ice was less extensive than at present. A century-long record covering the Kara, Laptev, East Siberian and Chukchi Seas²³ shows insignificant changes over the 20th century, which the authors pointed out “do not support the hypothesized polar amplification of global warming.” Researchers at Canada’s Institute of Ocean Sciences have also found that part of the measured change in Arctic sea ice thickness is due to prevailing wind systems pushing the ice to different locations, rather than the ice actually disappearing.²⁴

²⁰ See <http://www.jpl.nasa.gov/news/news.cfm?release=2007-131>

²¹ <http://www.co2science.org/scripts/CO2ScienceB2C/articles/V4/N23/C1.jsp>

²² <http://www.co2science.org/scripts/CO2ScienceB2C/articles/V4/N41/C1.jsp>

²³ <http://www.co2science.org/scripts/CO2ScienceB2C/articles/V7/N16/C1.jsp>

²⁴ Holloway, G. and Sou, T. (2002): Has Arctic sea ice rapidly thinned? *Journal of Climate* 15, 1691–701.

Global climate models project nearly symmetric effects on polar regions. So it is also noteworthy that there is no evidence of loss of Antarctic ice, and this year's Antarctic sea ice formation was at an all-time high in the satellite record.

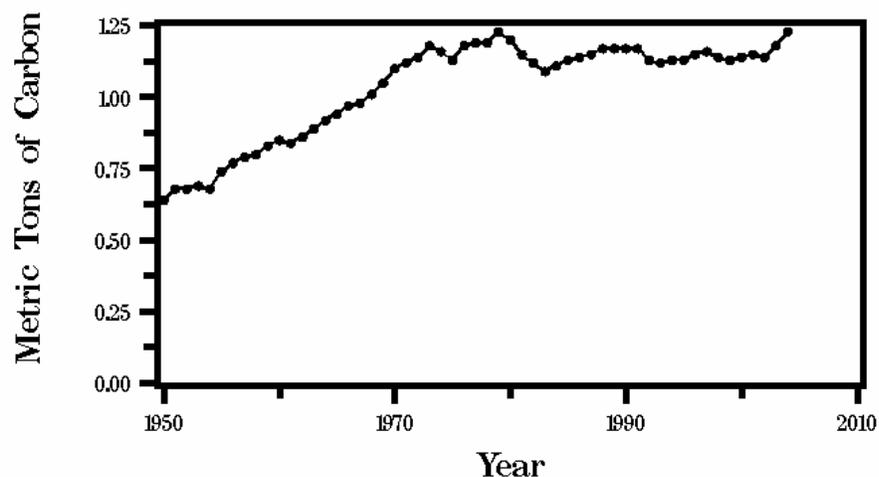
Implications

People notice compelling anecdotes, such as polar bears dying or ice caps melting, and these often make the nightly news. Be aware that in a topic as large and complex as global climate, it is easy to cherry-pick. As a policy maker you have the right, and duty, to ask to see *all* the data, including the historical context and the regional big picture. And be aware that people will tend to select data that helps them make their case. Make a point of asking people who hold a different view to provide the evidence that led them to their position. Let the data decide if the “science is settled.”

6. Despite some regional differences, climate models all agree that there will be global warming of 2°C to 6 °C over the next century, due to greenhouse gases.

The fact that all the models agree on warming means nothing, since they are all programmed to generate warming from CO₂ emissions. Climate models are programmed to have a climate sensitivity ranging from 2°C to 4.5°C mean response to a doubling of CO₂ levels. The IPCC uses emission scenarios to project changes over the next 100 years in global CO₂ levels. This range of emission scenarios, coupled with the assumed range of climate sensitivity parameters, yields the range of model projections. The range could be made wider or narrower simply by changing the models, or using different emission projections.

As for global CO₂ emissions, the IPCC uses an exaggerated range of forecasts. Global per capita carbon emissions have average 1.14 tonnes per person since 1970. There is no upward trend (though recent data has jumped to the high level reached back in 1979). 27 out of 40 of the IPCC emission forecasts assume that global per capita emissions will be permanently over 1.2 tonnes per person by 2020, and some put the number over 1.9 tonnes per person. In a paper I am working on with an American colleague, we are able to show that there is currently no basis for such a projection.



Global per capita carbon emissions from fossil fuel consumption
(<http://cdiac.esd.ornl.gov/trends/emis/glo.htm>)

If emissions remain in the 1.1-1.2 tonnes/capita range over the next few decades we will realize the lowest end of the IPCC emission scenarios. With a peak global population of 9 billion mid-century, average emissions of 1.2 tonne/person means total emissions of 11 Gigatonnes. IPCC projections almost all exceed this, ranging from 12 to 40 Gigatonnes as of 2050. To get total emissions into that range, per capita emissions would have to climb well above 1.3 tonnes per person and stay there. Otherwise, global demographics, which tell us the world population will begin declining after 2050, will put a natural cap on long term carbon emissions, keeping it down at the low end of IPCC forecasts.

Implications

From your perspective as a policymaker, for the purpose of thinking about when international action is warranted, I would scribble the number **1.3** on a Post-It note and stick it to your wall. If global per capita carbon emissions go above that, and stay there for five years or so, then the low-mid range IPCC projections begin to get relevant. Otherwise only the lowest range of IPCC emission projections are likely to be observed, and that certainly should have some bearing on the question of how urgent the international issue is seen to be.

The policy agenda

Let me conclude by commenting on some policy matters.

Population drives CO₂

At the global level, total CO₂ emission trends will closely follow global population and will almost certainly be far lower than most IPCC scenarios.

Air pollution is a different matter

CO₂ and air pollution are quite different matters. Air emissions, like sulphur dioxide, particulates, carbon monoxide and nitrogen oxides can be reduced with scrubbers, fuel processing, improved burners and so forth. Your country, like most industrialized countries, has successfully controlled many conventional air pollution sources in this way. But none of these methods work for CO₂. There are no CO₂ scrubbers, and there is no such thing as low-carbon coal. Hydrogen, solar and wind are the energy answers of the future—and they always will be. Regardless of how much hype and boosterism we hear from subsidy-seeking advocates of tomorrow's miracle technology, you cannot cap or reduce total carbon emissions under current technology without cutting income, or population, or both.

Pricing versus caps

Economists who have written on climate have long argued that it should be thought of as a *pricing* issue, not a *quantity* issue. Viewing it as a quantity issue means trying to figure out the right “cap” on emissions. But nobody knows what the right cap is. Politicians get together and toss around meaningless reduction targets: 10%, 20%, 50% etc.; while in reality not even the climate hardliners in the UK and Germany can stop their emissions from growing, without crushing their economies.

Viewing it as a pricing issue makes more sense. By using fossil fuels and releasing carbon, I am imposing a social cost on others. The cost is not infinite: some efforts to reduce those emissions might be worthwhile, but others would cost more than they are worth. If I am made to pay the social

cost, then I will seek out the those measures that reduce my emissions at the lowest cost, up to the point where it would cost me more to reduce emissions than the social cost they impose on others. That point represents the right balance. We want people to reduce emissions only up to the point where further emission cuts would amount to spending dollars to save dimes. As people start paying the social cost of carbon emissions, they will naturally, over time, work out the right emission reduction level. Set the right price and the market will find the right cap.

While we really have no idea what the right cap will be, there is lots of evidence that the right price of carbon emissions is likely fairly low. Economists have taken climate model outputs and examined how economies would be affected, adding up at the global level the costs (and benefits) of the changes. These total costs typically work out to less than \$10 US per tonne of carbon of emissions. The range isn't very wide. And remember, these calculations assume the climate models are right; they don't try to scale back the effects to adjust for possible exaggerations.

At a price of about \$5 per tonne, very little emission reduction would occur. That implies that there is no valid case for deep emission cuts, given our current understanding. It is a curious little secret of the Stern Review that he came to the same conclusion after reviewing the published, peer-reviewed literature. But since he wanted to advocate deep emission cuts anyway he had to go and work up a whole new set of preposterous cost numbers based on a new model never seen in the professional economics literature, which has since been roundly denounced by economists in the field.

My ideal policy agenda

If you were to ask me to write the global warming policy for your country, it would look like this.

- At the international level, I would set a condition that your country will consider participating in treaties to impose global caps on carbon emissions only if the global per capita carbon emissions level rises above 1.3 tonnes per person and remains there for at least 5 years. As long as it remains below that level at the global scale, there is no basis of support for medium and high-end IPCC emission scenarios and their accompanying global warming forecasts.
- I would announce that the clanging wreckage called the ETS in Europe has confirmed that cap and trade mechanisms simply do not work for carbon dioxide (they are inherently ill-suited), and we will use an emission tax instead.
- I would then contact the staff in the Finance Ministry who administer fuel excise taxes and ask them to work out the unit tax rate equivalent to \$5 (US) per tonne of carbon, for each of the major fuel types.
- I would have the fee evolve using the T3 pricing rule, which is explained in the attached Commentary for the UK journal *Environment and Energy*. (A much more detailed explanation is available at <http://ross.mckitrick.googlepages.com/T3tax.VV-online.pdf>.)
- For revenue-recycling, I would use an output-based rule patterned on the way Sweden taxes NO_x emissions from its power plants. There are 374 large, fuel-burning, power-generating facilities in Sweden. The government has continuous NO_x monitors on all their smokestacks, and firms pay a fee per tonne of emissions. But the funds do not go to the government, they go into a pool, and at the end of the year it is all paid back to the firms, divided up by their share of power production. Firms that produce lots of emissions and not much output pay a net charge, while firms that produce low emissions per unit of output get a net subsidy, at the expense of their high-emitting competitors. The industry as a whole pays nothing. In the six years

following the introduction of the NO_x charge/rebate system, emissions per plant fell on average by half, and emissions per Megawatt fell by one third, even without new regulations being imposed. And the government made nothing from the tax.

- I would group all major firms by output category. In Canada I would use the 5-digit North American Industrial Classification System; in your country there is likely something comparable. Within each group, firms would be given an exemption on emissions up to a level determined as ten percent below the group average emissions intensity for some baseline year (or some such). For the amount of emissions over the exemption level, firms would be charged the current emissions fee per tonne. The money would then be refunded among group members based on share of total (dollar-valued) sales for that year. This would reward firms that reduce their emissions per dollar of output, but without imposing an undue burden on any sector.
- I would not have the fee collected by the government. Instead I would put the job of administering the system out to competitive tender. A private accounting firm would be selected to obtain firms' fuel consumption and sales figures and work out who owes what. At the end of each year a firm would either get an invoice or a cheque, and when the transactions are complete the accounting firm would submit a final report confirming that everything was paid up properly.
- To the vast, city-sized bureaucracy busying itself with carbon micro-accounting, tracking every kilowatt used by every old lady's tea kettle, and every drop of diesel used by every farmer's manure wagon (yes, we have such bean-counters in Canada too), and thinking up new and ever-more vexatious ways to interfere with ordinary household consumption of goods that injure no one and bring convenience and pleasure to our lives; to them I would say thank you for your services, now go away and find something productive to do with the rest of your lives. I would say this confident that anything they were accomplishing, and much more besides, to reduce environmental harm, could be accomplished at lower cost and inconvenience with a well-designed price instrument and ordinary decentralized market behaviour.
- To business leaders who complain about a new tax, I would remind them that things might have been much worse (i.e. the European cap&trade system), and their industry as a whole does not send a penny to government.
- To environmentalists who complain that the emissions fee is too low to yield much emission reductions, I would say that the fee is low because the social costs of the emissions are low. If the damages due to carbon emissions go up, so will the fee. If emissions do not change much, that indicates that, at present, emissions should not change much.
- To the alarmists who say that this policy is far too weak, and that the IPCC Report shows the threat of rapid global warming is so severe that much more stringent measures are needed, I would say that I too have studied the IPCC Report, and that the policy is firmly based on its scientific findings. If the warming turns out to be as bad as some are suggesting, the emissions fee will rise rapidly, and carbon output will decline as a result. But I am not going to short-circuit the process by ramping up the carbon price on speculation. We will know soon enough if the fee should rise: the atmosphere itself will tell us.

Yours truly,

Ross McKittrick

Calling the Carbon Bluff

Why not tie carbon taxes to actual levels of warming? Both skeptics and alarmists should expect their wishes to be answered

Ross McKittrick
Department of Economics
University of Guelph

After much effort, G8 leaders agreed earlier this year to “stabilize greenhouse gas concentrations at a level that would prevent dangerous anthropogenic interference with the climate system.” This is the same wording as in Article Two of the UN Framework Convention on Climate Change, signed in 1992. In other words, after months of negotiations, world leaders agreed on a text they had already ratified 15 years earlier.

More recently, leaders at the APEC Summit in Australia agreed to set “aspirational” targets to reduce greenhouse gas emissions, some day, on a voluntary basis.

Meanwhile, at the other pole, people who worry about global warming have been ramping up the rhetoric of alarm. For instance, at a Senate hearing this year, Al Gore referred to a “planetary emergency” of such proportions that we have only 10 years to save our civilization from catastrophe.

Global warming policy is stuck between these poles of alarmism and inaction. The stalemate exists for very basic reasons. Reductions in greenhouse gas emissions (beyond trivial, symbolic gestures) are extremely costly. Such reductions may eventually turn out to be necessary, but important divisions of opinion remain on the extent of humanity’s influence on climate, whether or not the situation is a crisis, whether and how much greenhouse gas emissions should be cut, if so how to do it, and what is the most we should be prepared to pay in the process. For those convinced of the need to slash emissions now, the endless questioning seems frustrating and foolish. For those aware of the uncertainties, the proliferation of costly and pointless policy gimmicks (such as banning incandescent light bulbs or plasma TVs) in response to the political pressure to be seen doing “something” seems equally frustrating and foolish.

With this stalemate in mind, I would like to propose an approach to climate policy that could, in principle, get past the stalemate between unachievable targets and pointless gimmicks, while in principle getting equal support from all sides.

The approach is based on two points of expert agreement. First, most economists who have written on carbon dioxide emissions have concluded that an emissions tax is preferable to a cap-and-trade system. The reason is that, while emission abatement costs vary a lot based on the target, the social damages from a tonne of carbon dioxide emissions are roughly constant. The first ton of carbon dioxide imposes the same social cost as the last ton. In this case it is better for policymakers to try to guess the right price for emissions rather than the right cap.

A policymaker trying to guess the right emissions cap is guaranteed to get it wrong, and even small errors can cause huge economic problems, as Europe is discovering as it tries to make a go of its cap and trade system. But on the price side, most studies that have looked at the global social costs per tonne of carbon dioxide (assuming climate models are correct) have found it is likely to be quite low. Even among studies that take climate model projections at face value, the global damages in most of the serious published studies work out to be less than ten dollars (US) per tonne. Policymakers toss around emission cap proposals that vary all over the map: five percent, twenty percent, fifty percent, etc. The reality is that no one knows what the right emissions cap is. But if we want to charge emitters the social costs of their activities, the estimated price is likely to be low. If we put a charge of about five dollars (US) on each tonne of carbon emissions, the market will find the (roughly) correct emissions cap.

Second, climate models predict that, if greenhouse gases are driving climate change, there will be a unique fingerprint in the form of a strong warming trend in the tropical troposphere, the region of the atmosphere up to 15 km altitude, over the tropics from 20 degrees North to 20 degrees South.

This point has not been widely appreciated in the global warming discussion to date. People have come to see signs of “global warming” in the daily weather reports regardless of what happens—warming, freezing, rain, drought, wind, lack of wind, etc; much the way Nostradamus devotees see confirmations of his hazy prophecies in the daily news, no matter what happens or doesn’t happen. But while there are many hazy aspects to climate forecasts, the Intergovernmental Panel on Climate Change (IPCC) report from earlier this year puts its stock in the tropical troposphere trend as a clear, unique greenhouse signal that ought to be already visible and that ought to dominate future greenhouse warming. Figure 9.1 of the IPCC Working Group I Fourth Assessment Report presents a climate model hindcast from 1890 to 1999, breaking down expected 20th century changes by forcing factors. Climate changes due to solar intensification and other natural factors do not yield a pattern focused on the tropical troposphere: only greenhouse gas-induced warming does. And the effect is so strong as to dominate the total change. The same result emerges in the 1958-1999 hindcast shown on page 25 of the 2006 US Climate Change Science Program report. According to both assessments, greenhouse gases should have had a large effect on the tropical troposphere by now, it is uniquely associated with greenhouse gases, and it should dominate all other factors by now.

Projections of future climate changes are shown in Figure 10.7 of the IPCC report. In the on-line supplementary material there are twelve different model results shown, all yielding the identical pattern: a warming bullseye in the tropical troposphere that leads the process and exceeds the warming either at the tropical surface or in the global troposphere as a whole.

It is therefore convenient that we have good quality data for this region of the atmosphere. Temperatures in the tropical troposphere are measured every day using weather satellites and weather balloons. The satellite data are analysed by several teams, including one at the University of Alabama-Huntsville (UAH) and one at Remote Sensing Systems (RSS) in California. According to the UAH team, the mean tropical tropospheric temperature anomaly (its departure from the 1979-1998 average) over the past three years is 0.18 degrees C (as of May 2007). The corresponding RSS estimate is 0.29. Interestingly, neither the satellite data nor the weather balloon data show a statistically significant warming pattern in the tropical troposphere. The IPCC Report, Figure 3.4.3, shows that none of the available satellite or balloon measures of that region exhibit a significant warming trend. Additionally, the tropospheric warming is less than at the tropical surface in most data sets, and less than the global average, counter to model predictions. The US Climate Change Science Report found the same thing.

Leaving aside the model/data discrepancy, we can proceed by putting the science and policy ideas together. Suppose each country implements something called the T3 Tax, which stands for the Tropical

Tropospheric Temperature. The US dollar rate would be set equal to 20 times the three-year moving average of the RSS and UAH estimates of the mean tropical tropospheric temperature anomaly, assessed per tonne of carbon equivalent, updated annually. Based on current data the tax would be about US \$4.70 per tonne, which is about the median mainstream carbon dioxide damage estimate from a major survey published in 2005 by economist Richard Tol. The tax would be implemented on all domestic carbon dioxide emissions (assessed per tonne of carbon equivalent), all the revenues would be recycled into domestic income or industry tax cuts to maintain fiscal neutrality, and there would be no cap on total emissions.

This tax rate is proposed to begin at a low rate, where it would yield very little emissions abatement but would also be economically innocuous, at least at the macroeconomic level. Global warming skeptics and opponents of greenhouse abatement policy will like that. But would global warming activists? Initially no: they would argue it is ineffective. But if they understand both the climate model forecasts and the way investors make decisions, they should like the policy—because according to them, the tax will climb rapidly in the years ahead, and investors base their current decisions not on current prices but on expectations of future prices.

The IPCC predicts a warming rate in the tropical troposphere of about double that at the surface, implying about 0.2 to 1.2 degrees C per decade in the tropical troposphere under greenhouse forcing scenarios. That implies the tax will climb by \$4 to \$24 per tonne per decade, a more aggressive schedule of emission fee increases than most current proposals. At the upper end of warming forecasts, the tax could reach over \$200 per tonne of CO₂ by 2100, forcing major carbon emission reductions and a global shift to non-carbon energy sources.

If the “science is settled” and the “debate is over” and so forth, investors will know for sure that the carbon tax rate is going up rapidly, and will accordingly plan to scale back use of carbon-intensive energy. Global warming activists would like this. But would skeptics? They should, because if they really believe the models are exaggerating the warming forecasts they can be assured that the carbon tax will not rise. Skeptics can point to the fact that the averaged UAH/RSS tropical troposphere series went up only about 0.08 degrees C over the past decade, implying a decadal trend upward in the T3 tax of only \$1.60 if this trend continues. And the mean tropical tropospheric temperature has been going down since 2002. Some solar scientists even expect pronounced cooling to begin in a decade. If they are right, the T3 tax will fall to zero within two decades, and may even turn into a subsidy for carbon emissions.

At this point the global warming alarmists might be tempted to slam the proposal. But not so fast, Mr. Gore: the tax would only become a carbon subsidy if all the climate models are wrong, if greenhouse gases are not warming the atmosphere, if the sun actually controls the climate and if solar output weakens in the years ahead. Alarmists sneeringly denounce such claims as ‘denialism’ so they can hardly reject the T3 policy on grounds that take them as true. Instead they should cheerfully dismiss such concerns on the oft-repeated basis that there is no uncertainty, the debate is over, and global warming due to greenhouse gases is a settled scientific fact. If *that* is the case, the T3 tax will deliver the stringent carbon emission controls the alarmist side has been wanting.

Under the T3 tax, the regulator gets to call everyone’s bluff at once, without gambling in advance on who is right. If the tax goes up, it ought to have. If it doesn’t go up, it shouldn’t have. Either way we get a sensible outcome. The only people who lose will be those whose positions were disingenuous, such as opponents of greenhouse policy who claim to be skeptical while privately believing greenhouse warming is a crisis, or proponents of greenhouse gas emission cuts who neither understand nor believe the IPCC projections, but invoke them as a convenient argument on behalf of policies they want on other grounds even if global warming turns out to be untrue.

And the benefits don't stop there. The T3 tax will induce forward-looking behaviour. Alarmists worry that conventional policy operates with too long a lag to prevent damaging climate change. Under the T3 tax, investors planning major industrial projects will need to forecast the tax rate many years ahead, thereby taking into account the most likely path of global warming a decade or more in advance.

And best of all, the T3 tax will encourage private sector climate forecasting. Firms will need good estimates of future tax rates, which will force them to look deeply, and objectively, into the question of whether existing climate forecasts have an alarmist bias. The financial incentives will lead to independent re-assessments of global climate modeling, without regard to what politicians, the IPCC or climatology professors want to hear.

I have received some criticisms of this idea that need to be addressed. First, it seems to be backwards-looking, in that it is based on current and past temperature levels. So doesn't that mean it amounts to closing the barn door after the horse has fled? Actually no. By choosing the tropical troposphere as our metric we are using the atmosphere's own "leading indicator"—the warming there is supposed to be earlier and stronger than warming at the surface. And second, remember that investors are forward-looking. Somebody building a heavy oil upgrader or a pulp mill would not want to know the tax rate today, much less last year; instead he will want to know what the tax rate will be 10 or 20 years from now when the operation is at full capacity. Under the T3 rule, that estimate will have to be based on the best, most objective forecasts of climate change available. Firms will be worse off by either fudging the forecasts or ignoring sound scientific evidence: the best results will accrue to firms incorporating the most accurate climate forecasts into their decision-making, precisely the kind of forward-looking behaviour environmentalists want to encourage. Consequently it's not the case that we have to wait until it is "too late" to respond to global warming. The market will force investors to make the best possible use of information, and to press for improvements in climate forecasting in the process.

Having said that, it is entirely realistic to say that we need to see some actual warming before the climate policy gets stringent. Hard-liners on the policy side might want us to put such complete faith in climate models that we make huge policy investments based only on the assurance that a warming trend currently missing from the data is soon to be observed. But given the costs of large carbon emission reductions, and the apparent tendency of models to over-estimate of the effect of greenhouse gases, this is asking too much of society in general and policy makers in particular. Requirements of basic prudence is satisfied in this case by saying that the current and future changes in the tax rate ought to depend on seeing the actual tropical tropospheric trend, not simply seeing a computer model projection of what it might be, some time in the future.

Second, the tax I propose starts small, and environmentalists will object that at this rate it is too low to force emissions down. That is indeed correct. But it is low because the estimates of damages due to greenhouse gas emissions is low. What matters, from an economic point of view, is that emitters will be paying the estimated social costs of their actions. Once they are doing so, the market will find the right level of emissions, even if it is not much different from the unregulated emissions level, until the tax rate has risen substantially higher.

Policymaking in the real world is messy, and ideas that sound good in theory can come out hopelessly gummed up with extraneous provisions that dilute or contradict the original purpose. But as a thought experiment, I find the T3 tax clarifies a lot of issues. My personal view is that the ideal global warming policy is a carbon tax, and the optimal rate is zero. I like the T3 tax in part because I think it would result in this outcome over time. Yet those whose fears of rapid warming lead them to demand stronger policy measures should, in principle, equally be able to support the T3 tax since they expect it to yield stringent

emission controls in the years ahead. In light of the long stalemates over carbon dioxide emissions policy, I know of no other policy that can lay claim to equal support from such polarized camps.