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Senator James M. Inhofe
Ranking Member
Senate Committee on Environment and Public Works

Dear Senator Inhofe

Thank you for the opportunity to provide some information pertaining to the formulation of climate policy. Your questions, and my answers, are as follows.

1. As policymakers, it is our duty to ensure that models developed by the [Environmental Protection] Agency are useful for their intended purpose, articulate major assumptions and uncertainties, and separate scientific conclusions from policy judgments. Are the models and data relied on by the U.S. Climate Change Science Program and IPCC transparent and verifiable? Can you please comment on their transparency, including for example: whether they have been subject to credible, objective peer review and sensitivity and uncertainty analyses?

The models are superficially transparent because expert users can examine the code. However they are very complex, so their behaviour is not always comprehensible. The 4th IPCC Report, Working Group I (AR4 p. 594) notes:

> A climate model is a very complex system, with many components. The model must of course be tested at the system level, that is, by running the full model and comparing the results with observations. Such tests can reveal problems, but their source is often hidden by the model's complexity.

When models become "black boxes" that nobody can fully understand, direct transparency becomes impossible. At that point we rely on modelers to subject their models to full stress testing and to report the results without trying to conceal any problems exposed by the testing. It is essential that models not merely be "validated"—i.e. the tests cannot simply be designed to look for points of agreement with the data, but must seek out and rectify problems. Where assumptions and structures are refuted, they must either be corrected or the models discarded.

Hence the question of model transparency and testing is as much about the *communication* of testing results to potential users of the model outputs. To put the current issue into perspective, the United

States and, indeed, the rest of the world, is now experiencing a devastating economic contraction following the destruction of trillions dollars worth of American and European financial wealth through collapsing asset prices. A substantial part of the blame can be placed on a systemic failure to properly test the pricing models used to evaluate mortgage-backed securities and their derivatives. In a recent analysis of the global financial crisis, Canadian economist Frank Milne[1] observes that this came down, in part, to a failure of due diligence by users of the model outputs:

> Exuberance, naivety and the lure of large returns allowed many investors to overlook the limits of the models they were relying on, ignore the warning signals by central banks and others, and to skimp on their own due diligence. As the US housing market began to decline, the assumptions and empirical calibration of those models, and the construction of credit instruments and their packaging came into question. Lack of transparency became an increasing issue and liquidity in the relevant markets largely disappeared, as buyers refused to buy these instruments except at deep discounts. The real problem was not so much a lack of short-term liquidity, but very serious informational deficiencies compounded by a lack of transparency and trust. Many [financial institutions] began to worry about the solvency of, and their exposure to, other [financial institutions].
>
> The resulting crisis is having serious consequences for the US real economy, especially housing and consumer durable markets. Policy needs to address problems in US financial markets… If it is not successful, then there are concerns that their problems will multiply and spread internationally into a major systemic credit crisis that will cause a serious international recession.

I see many parallels between the economic crisis induced by an investment bubble in assets that had been systematically over-priced by financial models, and the disputes over how much nations should invest in green energy schemes and other greenhouse gas policies based on climate models that systematically over-predict the effects of carbon dioxide emissions. In hindsight we now know that we should have been far more skeptical about computerized financial models, we should not have assumed that because they all produced similar outputs they must all therefore be correct, we should not have assumed that the eminence of the professors who developed them ruled out the possibility that they could be fundamentally flawed, and we should have paid attention to the discrepancies between their structural features and observed reality (e.g. concerning liquidity of some asset markets). We should also have listened to those few isolated individuals who tried to warn international leaders that the "consensus" of financial experts masked serious problems of groupthink and blind momentum.

Likewise, skepticism about climate models must be strongly encouraged and where serious problems are identified, the models must be fixed or rejected. Yet skepticism about climate models is nowhere to be found in the prominent summaries coming from the IPCC and the Climate Change Science Program (CCSP). The CCSP report of June 2006 (*Temperature Trends in the Lower Atmosphere: Steps for Understanding and Reconciling Differences*) provides a striking example of this. In the Executive Summary the report describes a "potentially serious inconsistency" (p. 11) between model predictions and observed data in the tropical troposphere. All models predict amplified warming in the tropical troposphere as an essential component of the assumed greenhouse gas-induced global warming mechanism. Yet the numerous data sets analysed and scrutinized in the CCSP report fail to

[1] Milne, Frank (2008) "Anatomy of the Credit Crisis: The Role of Faulty Risk Management Systems" C.D. Howe Institute Commentary No. 269, July 2008.

show this pattern. Rather than acknowledge that the models appear to be wrong, the CCSP report claims that the models are probably right and the data are probably wrong, despite their failure across six chapters to find any specific flaws in the data beyond the ones that were rectified as part of the report-writing process:

> 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. (CCSP Report page 2)

Later (pages 10-11) the Summary cites model-to-model comparisons as evidence that the models are likely correct, and repeats its claim that the data are likely wrong. They go on to explain that to get agreement between models and data requires an assumption that greenhouse gases have little climatic impact, but then dismiss the assumption as unrealistic:

> 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.

Thus the CCSP decides on a model's "realism" not by its ability to match the data, but by how much its behaviour matches the modelers' assumptions. The controlling influence of this assumption is evident throughout the CCSP report and, in my view, substantially diminishes the credibility of its conclusions.

The main tool for testing any kind of model is to examine its accuracy in reproducing past events, and to show on theoretical grounds that such fidelity implies accuracy in forecasting. Considering the magnitude of the policy decisions resting on climate model output, it is important to note the IPCC's admission that this kind of testing has barely begun:

> What does the accuracy of a climate model's simulation of past or contemporary climate say about the accuracy of its projections of climate change? This question is just beginning to be addressed, exploiting the newly available ensembles of models….the development of robust metrics is still at an early stage.
> (AR4 Working Group I pp. 594-5).

In the Second Order Draft of the 4th IPCC Report (AR4), at the close of scientific review (June 2006) the text stated that even models tuned to "perfectly" reproduce the observed climate did not necessarily have predictive ability.

> [P]reliminary studies relying on "perfect model" simulations (e.g., Murphy et al., 2004; Stainforth et al., 2005) show only a weak relationship between certain measures of model skill in simulating climatology and the accurate prediction of future climate, so at this time it is impossible to establish minimum threshold criteria that models must meet to be trusted as reliable prediction tools. Nevertheless, poor model skill in simulating present climate indicates that certain physical processes have been misrepresented.
> (Working Group I Second Draft, page 8-18).

This paragraph was heavily edited prior to release of the published version, as follows

> ~~[P]reliminary studies relying on "perfect model" simulations (e.g., Murphy et al., 2004; Stainforth et al., 2005) show only a weak relationship between certain measures of model skill in simulating climatology and the accurate prediction of future climate, so at this time it is impossible to establish minimum threshold criteria that models must meet to be trusted as reliable prediction tools.~~ Poor model skill in simulating present climate ~~indicates~~ could indicate that certain physical or dynamical processes have been misrepresented.
> (Working Group I Report, page 608).

While the IPCC makes some effort to evaluate their models, and they counsel caution in using model results, they have not identified whether their models can be or have been falsified, and even downplay the idea of such testing. For instance, on page 594 of the Working Group I contribution to the AR4, they state:

> A specific prediction based on a model can often be demonstrated to be right or wrong, but the model itself should always be viewed critically. This is true for both weather prediction and climate prediction. Weather forecasts are produced on a regular basis, and can be quickly tested against what actually happened. Over time, statistics can be accumulated that give information on the performance of a particular model or forecast system. In climate change simulations, on the other hand, models are used to make projections of possible future changes over time scales of many decades and for which there are no precise past analogues. Confidence in a model can be gained through simulations of the historical record, or of palaeoclimate, but such opportunities are much more limited than are those available through weather prediction.

Notice that they only describe a process that builds confidence in models, without specifying circumstances in which climate models can might actually be refuted.

In the body of the IPCC AR4 there are numerous warnings about the limited accuracy of climate models, but these were omitted from the Summary for Policymakers. Section 8.1.3.1 cautions that fundamental climatic processes are represented in models by approximations that may have little or no empirical basis, and that there has been no formal evaluation of whether models are "overfit" against the data, which would mean their fidelity to observed climate conditions is meaningless as a test of forecast skill:

> Parametrizations are typically based in part on simplified physical models of the unresolved processes (e.g., entraining plume models in some convection schemes). The parametrizations also involve numerical parameters that must be specified as input. Some of these parameters can be measured, at least in principle, while others cannot. It is therefore common to adjust parameter values (possibly chosen from some prior distribution) in order to optimise model simulation of particular variables or to improve global heat balance. This process is often known as 'tuning'. It is justifiable to the extent that two conditions are met:
>
> 1. Observationally based constraints on parameter ranges are not exceeded. Note that in some cases this may not provide a tight constraint on parameter values (e.g., Heymsfield and Donner, 1990).

2. The number of degrees of freedom in the tuneable parameters is less than the number of degrees of freedom in the observational constraints used in model evaluation. This is believed to be true for most GCMs – for example, climate models are not explicitly tuned to give a good representation of North Atlantic Oscillation (NAO) variability – but no studies are available that formally address the question. If the model has been tuned to give a good representation of a particular observed quantity, then agreement with that observation cannot be used to build confidence in that model.

(Working Group I Report p. 596).

They also warn that cloud processes are highly influential on model results, yet are poorly represented in models and it is not yet possible to resolve the differences among models:

> Recent studies reaffirm that the spread of climate sensitivity estimates among models arises primarily from inter-model differences in cloud feedbacks. The shortwave impact of changes in boundary-layer clouds, and to a lesser extent mid-level clouds, constitutes the largest contributor to inter-model differences in global cloud feedbacks. The relatively poor simulation of these clouds in the present climate is a reason for some concern.
>
> The response to global warming of deep convective clouds is also a substantial source of uncertainty in projections since current models predict different responses of these clouds. Observationally based evaluation of cloud feedbacks indicates that climate models exhibit different strengths and weaknesses, and it is not yet possible to determine which estimates of the climate change cloud feedbacks are the most reliable.
>
> (Working Group I Report p. 593).

These are all germane points, and imply that the results of climate modeling (including attribution of past warming to greenhouse gases as well as predictions of future warming) are inherently uncertain and tentative. But none of this went into the Summary for Policymakers, whose only comment on model assessment was:

> Advances in climate change modelling now enable best estimates and *likely* assessed uncertainty ranges to be given for projected warming for different emission scenarios.
>
> (SPM page 13, emphasis in original)

This is clearly an inadequate summary of the situation, to the point of being misleading. Hence, in response to the first question, the IPCC Report indicates that rigorous, objective assessment of model accuracy is only at an early stage, and that there are major limitations and deficiencies in climate models, but this information was omitted from the IPCC's Summary for Policymakers.

2. There has been increasing concern among climatologists and statisticians that existing models have limited abilities in predicting localized effects. In your professional opinion, how accurate are the global models at mimicking atmospheric processes as they relate to effects on local climates?

The key testing ground for climate models is their prediction concerning amplified warming in the troposphere over the tropics. Held and Soden (2000, p. 471)[2] discuss the importance of observing an accumulation of water vapor in the tropical troposphere as follows:

> 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.

It is now 10 years since they wrote that statement. Yet rather than squarely facing up to the possible falsification of climate models by reporting tests of models against the tropical troposphere, the IPCC repeatedly compares model outputs to surface data. The surface data are known to be biased due to land-use modification and other sources of artificial warming.[3] There is clear evidence of an upward bias, especially after 1980, in global land surface temperature records due to well-documented data quality problems. This should be borne in mind when examining the striking Figure on page 11 of the IPCC Summary for Policymakers (see below) which they present as evidence of greenhouse gas-induced warming. The Figure shows a divergence between model-generated estimates of averaged land surface temperatures after 1980 without greenhouse gas effects (blue band) and with greenhouse gas effects (red band); and the latter neatly overlaps the temperature record (black line). This is the basis for their claim that greenhouse gas effects have caused the observed warming.

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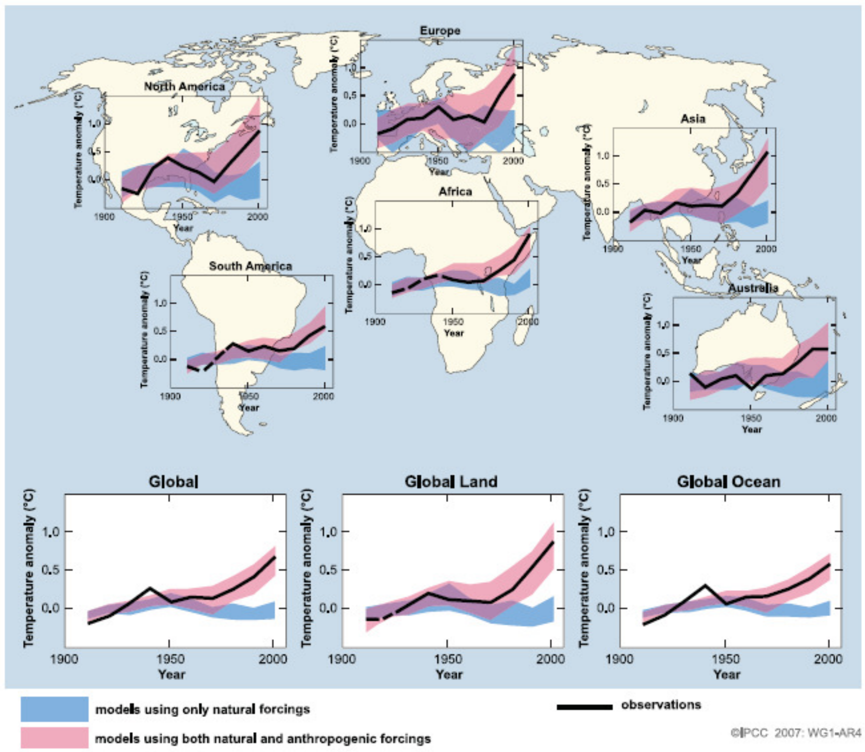
[2] Held, I. and B. J. Soden (2000) "Water Vapor Feedback and Global Warming" *Annual Review of Energy and Environment* 25:441—75.

[3] Pielke R.A. Sr., G. Marland, R.A. Betts, T.N. Chase, J.L. Eastman, J.O. Niles, D.D.S. Niyogi and S.W. Running. (2002) "The Influence of Land-use Change and Landscape Dynamics on the Climate System: Relevance to Climate-Change Policy Beyond the Radiative Effect of Greenhouse Gases." *Philosophical Transactions of the Royal Society of London*. A360:1705-1719; McKitrick, R and P. J. Michaels (2004). "A Test of Corrections for Extraneous Signals in Gridded Surface Temperature Data" *Climate Research* 26(2) pp. 159-173. "Erratum," *Climate Research* 27(3) 265—268. McKitrick, Ross R. and P.J. Michaels (2007) "Quantifying the influence of anthropogenic surface processes and inhomogeneities on gridded global climate data." *Journal of Geophysical Research*, 112, D24S09, doi:10.1029/2007JD008465, 2007; De Laat, A.T.J., and A.N. Maurellis (2004). "Industrial CO_2 Emissions as a Proxy for Anthropogenic Influence on Lower Tropospheric Temperature Trends." *Geophysical Research Letters* Vol. 31, L05204, doi:10.1029/2003GL019024. De Laat, A.T.J., and A.N. Maurellis (2006). "Evidence for Influence of Anthropogenic Surface Processes on Lower Tropospheric and Surface Temperature Trends." International Journal of Climatology 26:897—913.

GLOBAL AND CONTINENTAL TEMPERATURE CHANGE



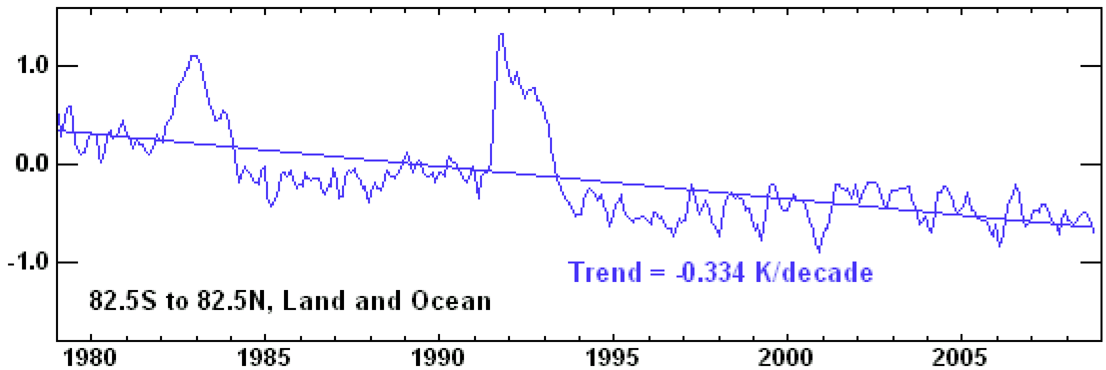
IPCC Summary for Policymakers page 11.

The blue and red bands diverge after about 1980. The blue band is generated by considering only solar changes and volcanic events as represented in the models. The red band is generated by adding a strong greenhouse gas warming effect. What they do not show is a case in which the model is run with natural forcings plus land surface modifications, urbanization and other data contamination problems, but little or no greenhouse gas warming. Depending on parameter choices this could also generate a band like the red one. Hence the presentation of modeling results in the Summary for Policymakers proves nothing, it is simply a selective and promotional insinuation.

Turning to the question of model fidelity in the troposphere, this issue is passed over in the Summary for Policymakers with the following claim (Summary for Policymakers p. 10)

> Warming of the climate system has been detected in changes of surface and atmospheric temperatures in the upper several hundred metres of the ocean, and in contributions to sea level rise. Attribution studies have established anthropogenic contributions to all of these changes. The observed pattern of tropospheric warming and stratospheric cooling is *very likely* due to the combined influences of greenhouse gas increases and stratospheric ozone depletion. {3.2, 3.4, 9.4, 9.5}

I will make one brief comment about the stratosphere, but otherwise confine my comments to the tropospheric record. The stratospheric record from Remote Sensing Systems in California looks as follows:



Source: http://www.remss.com/data/msu/graphics/plots/sc_Rss_compare_TS_channel_tls_v03_2.png

The models predict that there should be cooling at this layer in response to additional GHG's. The trend line makes it appear that cooling of about 0.33 °C/decade has occurred. However, all the cooling occurs in two steps, each one coinciding with a major volcanic eruption (El Chichon and Pinatubo). Since 1994 there has been no cooling trend, despite a 7% increase in the atmospheric CO_2 content (from 359 to 384 ppm). This does not strike me as a vindication of the model's prediction. However, I will confine my remarks to the tropospheric case.

Fidelity to tropical tropospheric observations matter because the region is essential to the assumed model structure and because the data are largely uncontaminated by the kinds of measurement problems known to affect land and ocean surface series.[4] The 2007 Intergovernmental Panel on Climate Change (IPCC) Report, Working Group I, Figure 9.1 (p. 675) presents a "backcast" analysis of the atmospheric response to observed changes in major forcings (greenhouse gases, solar radiation, volcanoes, aerosols and ozone depletion) over the interval 1890 to 1999 using the Parallel Climate Model (PCM), a large general circulation model sponsored by the US Department of Energy. The IPCC Figure is reproduced on the next page. I have added titles to the panels for ease of reading. All models are similar in behaviour, as the IPCC Report states (p. 674) that "The major features shown in Figure 9.1 are robust to using different climate models."

[4] The next few pages repeat text and graphics from a letter I sent to Hon. John Dingell in response to questions from the House Energy and Commerce subcommittee on Energy and Air Quality.

Chapter 9 Understanding and Attributing Climate Change

From 2007 IPCC Report page 675

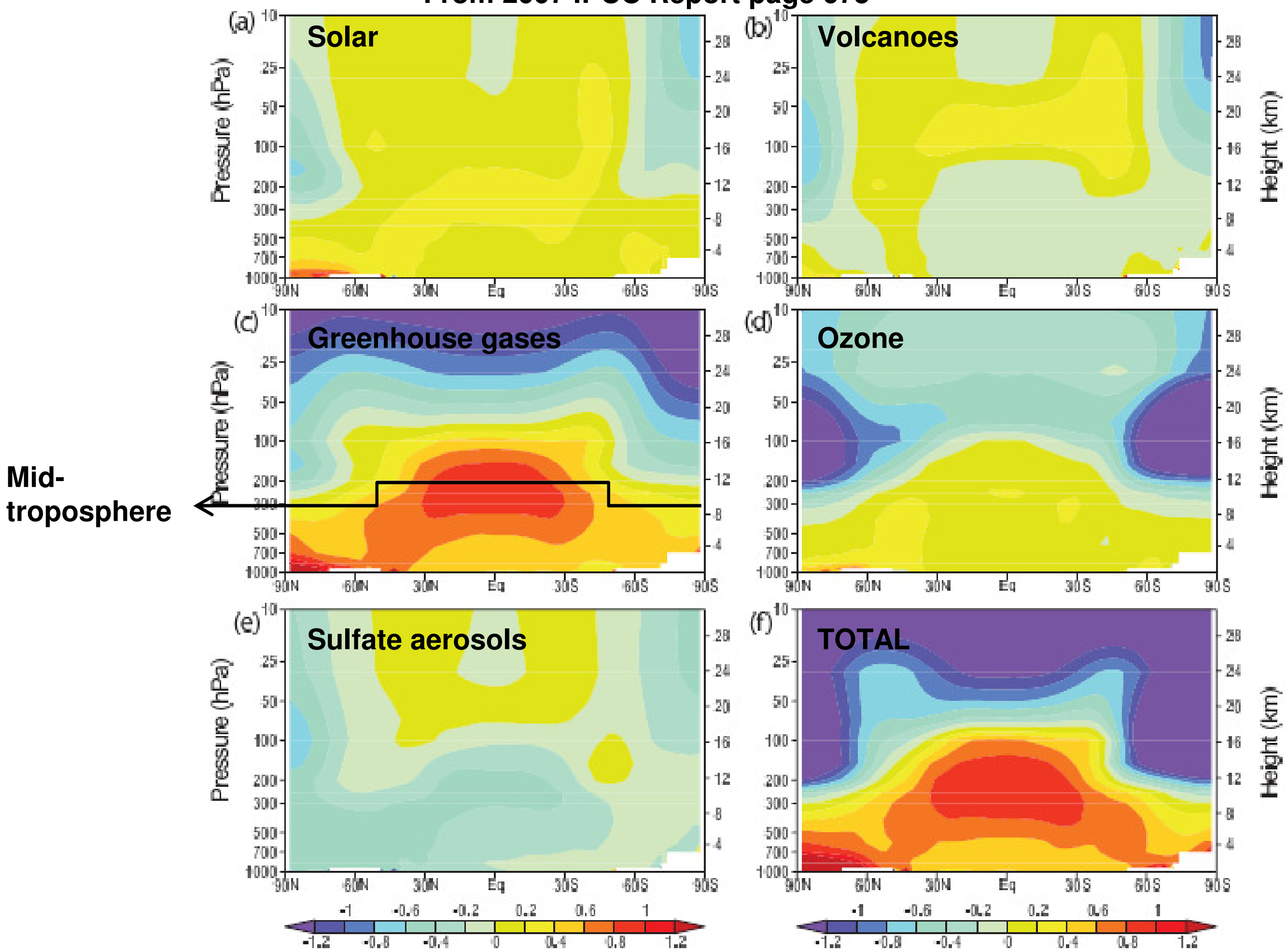


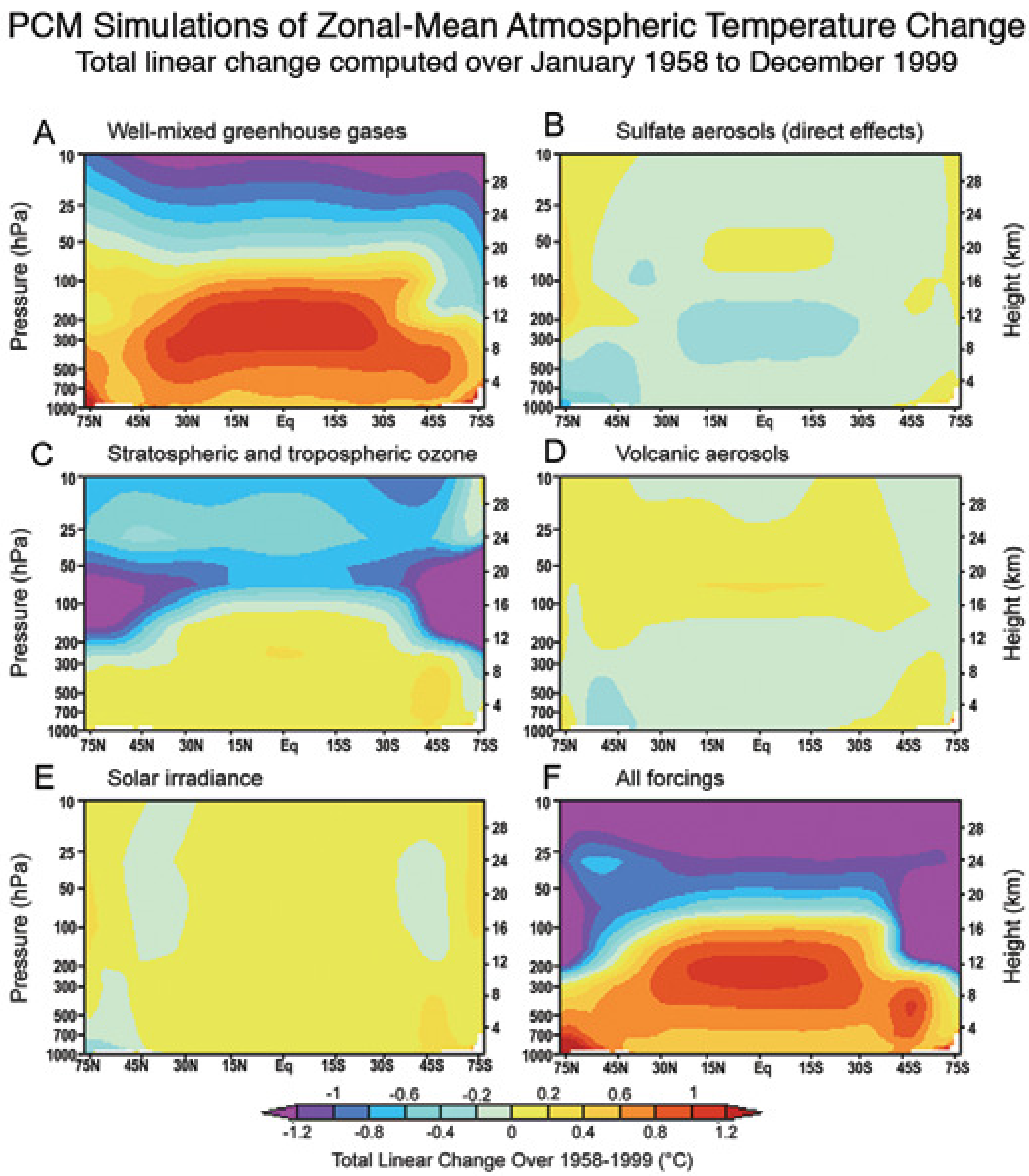
Figure 9.1. *Zonal mean atmospheric temperature change from 1890 to 1999 (°C per century) as simulated by the PCM model from (a) solar forcing, (b) volcanoes, (c) well-mixed greenhouse gases, (d) tropospheric and stratospheric ozone changes, (e) direct sulphate aerosol forcing and (f) the sum of all forcings. Plot is from 1,000 hPa to 10 hPa (shown on left scale) and from 0 km to 30 km (shown on right). See Appendix 9.C for additional information. Based on Santer et al. (2003a).*

The format of each panel is as follows. Latitude goes from left to right, with the North Pole at the left, the equator in the middle and the South Pole at the right. Altitude is on the vertical axis, beginning at the surface and rising through the troposphere and into the stratosphere. The colour represents the predicted temperature change in response to the forcing. Dark blue and purple represent strong cooling. As the shading moves through light blue, light yellow and into orange and red the implied temperature change moves upwards towards strong warming.

I have added a horizontal line in the Greenhouse Gases panel indicating the approximate height of the mid-troposphere: just over 8 km at the poles, rising to about 12 km in the tropics.

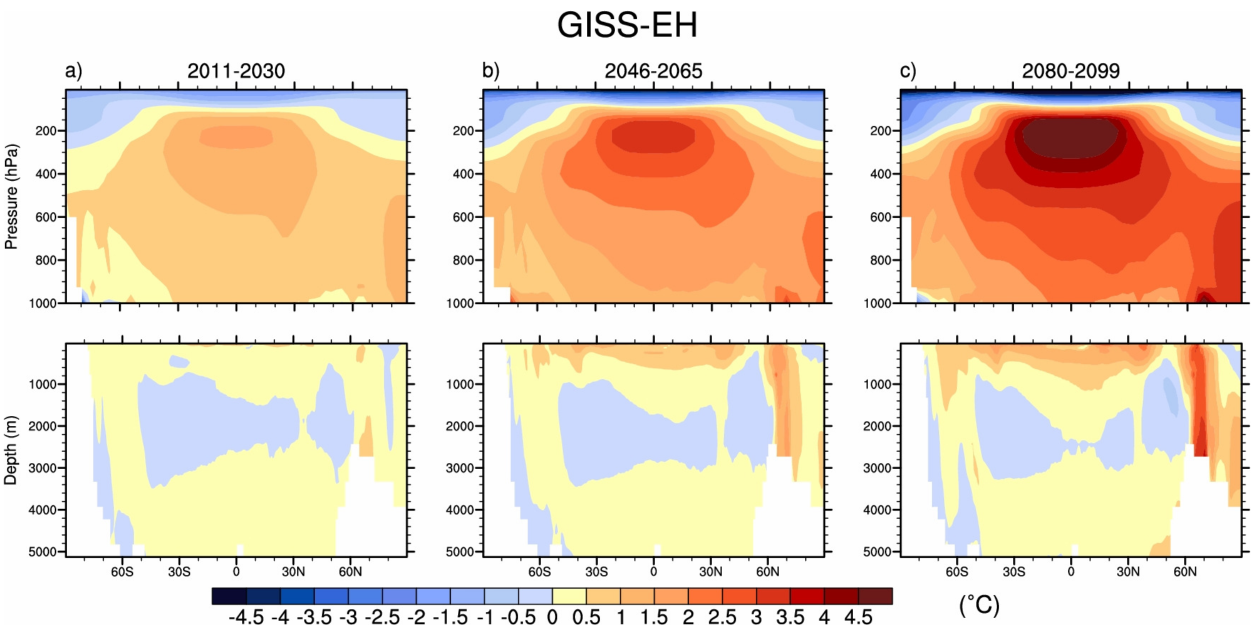
As is clear from the coloring gradient, the model troposphere over the tropics shows greater sensitivity to greenhouse gas accumulation than does the troposphere over the polar region. The color tones indicate that, in response to 20th century greenhouse gas accumulation, the model says there ought to have been a warming rate of over 1 C per century in the troposphere over the tropics, and about 0.4 C per century in the troposphere over the poles. This pattern is sufficiently large in comparison to all other forcings that it dominates the Total forcing pattern in the bottom right panel.

The CCSP report of 2006 presented very similar results for a more recent interval. I have reproduced Figure 1.3 (p. 25) below. It is similar in structure to the above IPCC diagram, and comes from the same model (PCM), but covers the interval 1958-1999. The color coding indicates once again that the troposphere is expected to be more sensitive to greenhouse gases over the tropics than over the polar regions (though note that regions beyond 75N and 75S are not displayed). In this case the warming rate in the mid-troposphere over the tropics is projected to be between 1.0 and 1.2 C over a 40 year span, or about 0.25-0.30 °C/decade, versus about 0.05-0.10 °C per decade over the poles, in the decades ending at 1999.



Turning now to projections of the climatic response to future increases in greenhouse gases, I have reproduced below one of the 12 climate model projections used for Figure 10.7 of the IPCC Report (p. 765). The models show the response to the A1B emissions scenario, which is in the middle of the group of IPCC climate simulations (see IPCC Figure 10.4). All 12 model runs are available on-line at http://ipcc-wg1.ucar.edu/wg1/Report/suppl/Ch10/Ch10_indiv-maps.html. The printed version of Figure 10.7 uses stippling to show the uniformity of results across models, but this makes it harder to see the color gradients, so I have selected the output from a single model, the Goddard Institute of Space Studies (GISS) model EH, for increased clarity.

The panels in the top row are each in the same format as those in the PCM diagrams above, except that, going from left to right, latitude runs from South to North, and the vertical axes do not extend as far up into the stratosphere. The bottom three panels show projected oceanic changes.



Source: http://ipcc-wg1.ucar.edu/wg1/Report/suppl/Ch10/indiv_maps/html/GISS-EH_10.7.html

The color coding indicates, over the indicated interval, the predicted change in the mean temperature compared to the observed mean temperature over the 1980 to 1999 interval. As before, the mid-troposphere over the tropics (300-200hPa) is projected to be more sensitive to increased greenhouse gas levels than the troposphere over the polar regions, in all time intervals. The accompanying IPCC text (pp. 764-765) states:

> Upper-tropospheric warming reaches a maximum in the tropics and is seen even in the early-century time period. The pattern is very similar over the three periods, consistent with the rapid adjustment of the atmosphere to the forcing. These changes are simulated with good consistency among the models.

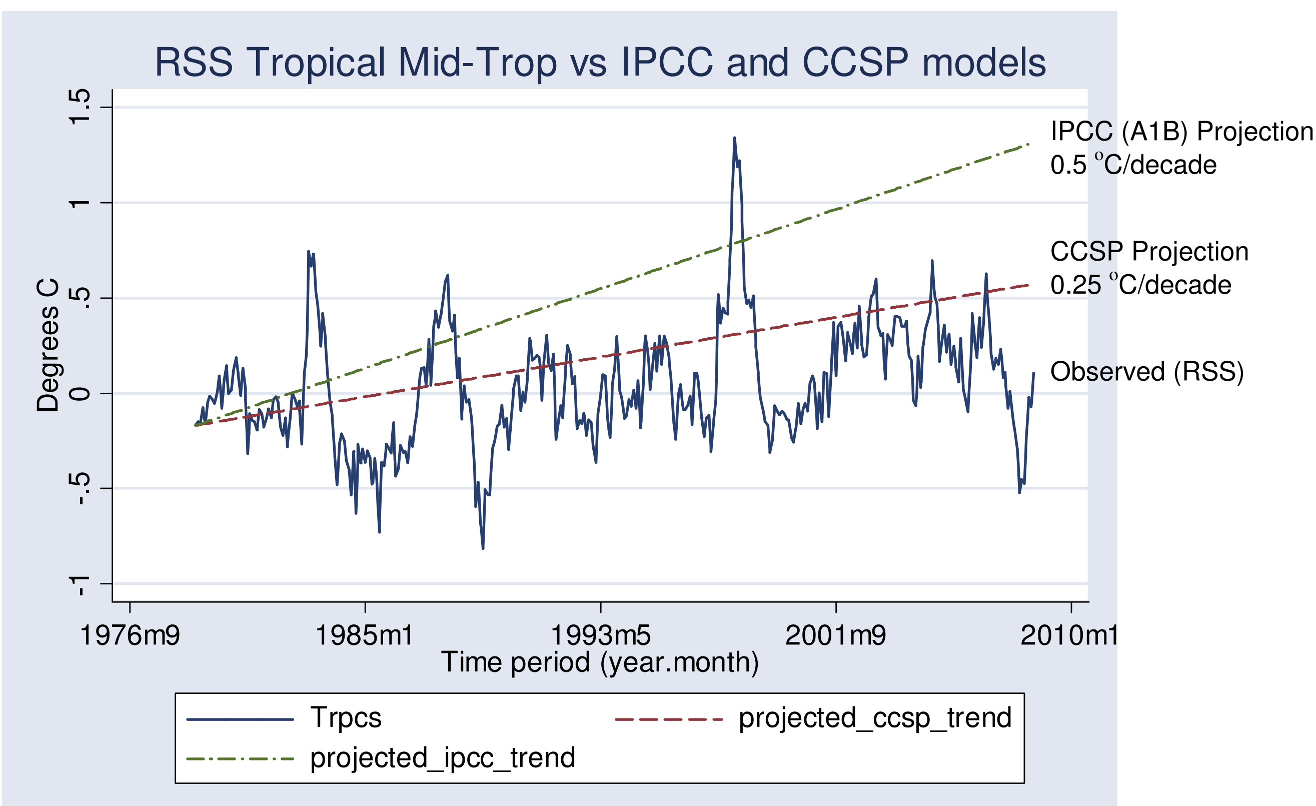
As of the 2011-2030 interval the troposphere over the tropics is projected to be about 1.5 ^{o}C warmer than the average temperature over the 1980 to 1999 interval. Comparing interval midpoints (1990, 2020) this implies a current average warming of 0.5 ^{o}C per decade, noting once again the statement in the IPCC text that this change should be observed even in the early-century time period.

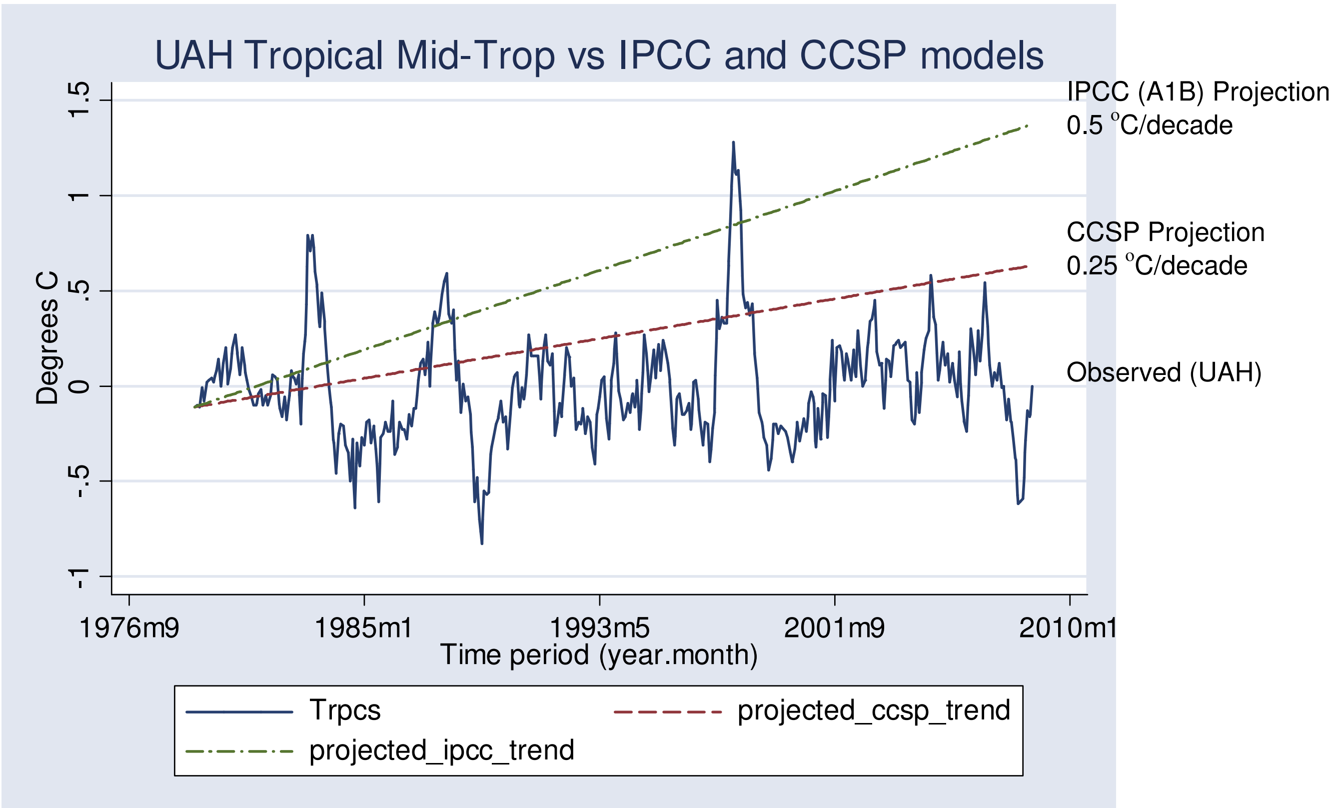
To summarize thus far, all the models which have been used for the IPCC and CCSP reports embed parameterizations that yield the following predictions:

- » The troposphere over the tropics should exhibit greater warming (more than double the rate) than the troposphere over the polar regions.
- » The effects induced by greenhouse gases are so large relative to other forcings (positive and negative) that the total pattern is predominantly a reflection of the contribution of greenhouse gases.
- » The tropical troposphere should have been heating up at a rate of at least 0.25 ^{o}C/decade over the past few decades in response to historical greenhouse gas emissions. A middle-range warming projection scenario in the IPCC report predicts warming of about 0.5 ^{o}C/decade should now be observable in the tropical mid-troposphere.

Since the models make such consistent predictions there is obvious interest in comparing model outputs to the available data: a comparison conspicuously absent from the IPCC Summary for Policymakers. Fortunately the data from weather satellites now spans nearly 30 years and is adequate to assess the model predictions.

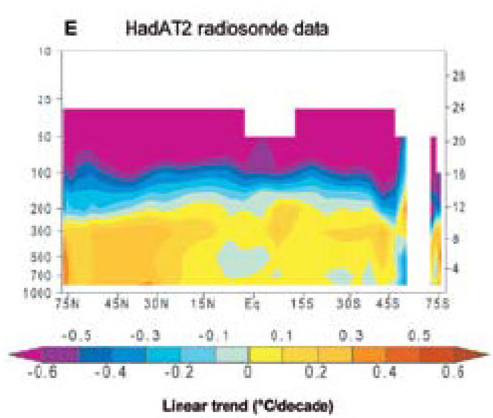
Weather satellite records for the mid-troposphere are available from Remote Sensing Systems (RSS) in California and the Earth Systems Science Center at the University of Alabama-Huntsville (UAH). I obtained the data from each lab for the mid-troposphere layer covering January 1979 to September 2008. Over this interval the annual average atmospheric concentration of CO_2 measured at Mauna Loa Hawaii rose from 337 ppm to 384 ppm (http://cdiac.ornl.gov/ftp/trends/co2/maunaloa.co2), a 14% increase. I have graphed the RSS and UAH tropical mid-troposphere series and compared them to the CCSP- and IPCC-predicted trends (0.25 ^{o}C/decade and 0.5 ^{o}C/decade respectively).





In contrast to climate model predictions the data indicate neither significant warming in the tropics nor greater warming than at the poles.

The CCSP report (Figure 5.7, p. 116) presented an atmospheric weather balloon series for the interval 1979-1999, (Hadley AT2) in a format similar to the backcast panels. Note that data over Antarctica is not shown.



From the color coding one can readily tell that, like the satellites, this balloon record exhibits no overall warming pattern in the tropical troposphere: instead there is slight cooling at lower altitudes, and minimal warming at the upper altitudes. The tropospheric warming is at a lower rate than in the troposphere as a whole and lower in comparison to the North Pole region. The CCSP text (fn 66, p. 115) points out that this data span includes the 'end-point effect' of the powerful 1998-1999 El Nino so the absence of tropical tropospheric warming is an even more conspicuous discrepancy with the models.

I computed linear trends (in ^{o}C/decade) for the most up-to-date RSS and UAH data, which are as follows. An asterix (*) denotes the trend is statistically significant, i.e. distinguishable from random fluctuations.

Atmospheric Region	**Remote Sensing Systems**	**University of Alabama**
	Temperature trend in C/decade, 1979:1 to 2008:9 (Std Error of trend in parentheses)	
Globe	0.09* (0.042)	0.04 (0.040)
North Pole	0.25* (0.058)	0.23* (0.058)
Northern Hemisphere	0.15* (0.045)	0.09* (0.040)
Tropics	0.11 (0.074)	0.03 (0.071)
Southern Hemisphere	0.03 (0.036)	-0.01 (0.034)
South Pole	-0.11 (0.070)	-0.12 (0.073)

Temperature trends in mid-troposphere, January 1979 to September 2008. Sources: http://www.remss.com/pub/msu/monthly_time_series/RSS_Monthly_MSU_AMSU_Channel_TMT_Anomalies_Land_and_Ocean_v03_2.txt http://vortex.nsstc.uah.edu/data/msu/t2/uahncdc.mt Trend regression computed using STATA arima(1,0,1) specification: code posted at http://ross.mckitrick.googlepages.com/S.Dingell.zip.

The satellite data reveal warming in the mid-troposphere over the northern high latitudes but little elsewhere: in particular none over the Southern Hemisphere and a cooling trend at the South Pole. Both satellite series confirm the absence of a significant warming trend in the tropical mid-troposphere.

In both the RSS and UAH data sets there is a slight upward global trend, which in neither case exceeds 0.1 ^{o}C per decade over the past 30 years, despite the addition of 47 ppm CO_2 to the atmosphere. This is well below the range of 0.25-0.5 ^{o}C/decade predicted by climate models. In both the RSS and UAH series the tropical trend about equals the global trend, whereas models predict it should exceed the global trend and be at least double that over each pole. In neither data set does the tropical region exhibit a larger trend than the North Pole; and in both data sets the South Pole has cooled, opposite to the backcast results in the IPCC and CCSP reports.

The satellite series differ in part because of their treatment of inter-satellite calibration in the early segment, with the RSS series initially tracking lower than the UAH series, yielding higher trend values over the entire sample. But over the past decade (January 1999 to September 2008) the UAH series has exhibited larger warming trends than the RSS data, and no region exhibits statistically significant warming in either data set. The RSS series since 1999 shows cooling over the Southern Hemisphere, and a global trend of only 0.006 ^{o}C/decade, despite a 4% rise in atmospheric CO_2 over this interval.

In light of the obvious mismatch between model predictions and observed data we can turn to the IPCC Report Chapter 9 in search of the basis for the Summary's claim that greenhouse gases "Very Likely" account for the tropospheric warming. Section 9.4.4.1 states:

> Since 1979, it is likely that there is slightly greater warming in the troposphere than at the surface, although uncertainties remain in observed tropospheric warming trends and whether these are greater or less than the surface trend.

This is a very weak claim and hardly establishes a "very likely" conclusion, especially since the next sentence concedes that their data does not show the pattern.

> The range (due to different data sets) of the global mean tropospheric temperature trend since 1979 is 0.12°C to 0.19°C per decade based on satellite-based estimates (Chapter 3) compared to a range of 0.16°C to 0.18°C per decade for the global surface warming.

The section that explores the tropical trend differences (9.4.4.4) reads as follows (emphasis added):

> Subtracting temperature trends at the surface from those in the free atmosphere removes much of the common variability between these layers and tests whether the model-predicted trends in tropospheric lapse rate are consistent with those observed by radiosondes and satellites (Karl et al., 2006). Since 1979, globally averaged modelled trends in tropospheric lapse rates are consistent with those observed. **However, this is not the case in the tropics, where most models have more warming aloft than at the surface while most observational estimates show more warming at the surface than in the troposphere** (Karl et al., 2006). Karl et al. (2006) carried out a systematic review of this issue. There is greater consistency between simulated and observed differential warming in the tropics in some satellite measurements of tropospheric temperature change, particularly when the effect of the cooling stratosphere on tropospheric retrievals is taken into account (Karl et al., 2006). External forcing other than greenhouse gas changes can also help to reconcile some of the differential warming, since both volcanic eruptions and stratospheric ozone depletion are expected to have cooled the troposphere more than the surface over the last several decades (Santer et al., 2000, 2001; IPCC, 2001; Free and Angell, 2002; Karl et al., 2006). There are, however, uncertainties in quantifying the differential cooling caused by these forcings, both in models and observations, arising from uncertainties in the forcings and model response to the forcings. Differential effects of natural modes of variability, such as ENSO and the NAM, on observed surface and tropospheric temperatures, which arise from differences in the amplitudes and spatial expression of these modes at the surface and in the troposphere, make only minor contributions to the overall differences in observed surface and tropospheric warming rates (Santer et al., 2001; Hegerl and Wallace, 2002; Karl et al., 2006).

To summarize, the crucial model-data mismatch in the tropics is acknowledged in the depths of the IPCC report, but is not only omitted from the Summary but is misrepresented altogether. The Summary claims that greenhouse gases are "very likely" responsible for the observed pattern of tropospheric warming pattern, yet the observed pattern is *opposite* to that predicted by the models.

Thus, in answer to the question, the models predict a specific atmospheric process in the tropical troposphere and indicate it is key to the global warming mechanism. Yet it does not match the observed data. Hence I find the models insufficiently accurate for predicting global, let alone local, effects. Furthermore, the misrepresentation of this problem by the IPCC Summary is an example of the lack of transparency that impedes due diligence and accurate decision-making.

3. What is the current state of U.S. models in their ability to accurately asses sources and sinks of greenhouse gases at the local, state and regional levels?

This is not an area I have any ability to comment on.

4. As policy discussions advance in the next Congress, do you believe climate models exist that are capable of focusing on particular areas to give more reliable predictions for the future? If not, ion you estimate, how long until such models can be developed?

Based on the above, it appears that models exist that can be matched to the data. According to the CCSP report quoted earlier, the ones that show the best fit to the data show little warming in response to greenhouse gases. In view of the available data, especially the satellite series from the tropical troposphere, I think this is likely to be the most correct view, and models that assume a large warming effect from CO_2 emissions will be found increasingly at odds with reality in the years ahead.

If I can be of any further assistance please let me know.

Yours truly,

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