

AN UNSCIENTIFIC “SCIENCE BRIEF” BY THE
PEW CENTER ON
“THE CAUSES OF GLOBAL CLIMATE CHANGE”

Analysis and Response

By

Science and Public Policy Institute



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AN UNSCIENTIFIC “SCIENCE BRIEF” BY THE PEW CENTER ON “THE CAUSES OF GLOBAL CLIMATE CHANGE”

The *soi-disant* “Science’ Brief” on “global warming” by the Pew Center¹ merely compounds the errors and half-truths already widely circulated in the IPCC’s 2007 climate assessment. There is little of what Pew calls “strong evidence” that anthropogenic greenhouse gases have contributed significantly to the “global climate change” observed during the 20th century.

Phrases like “recent scientific progress”, “science has made great strides recently”, “scientific understanding of the causes of climate change has progressed dramatically” are unsupported by credible scientific evidence, and are founded upon questionable and outdated results and data.

In this review, the Science and Public Policy Institute² exposes elementary errors of science in an apparently authoritative but actually inaccurate and misleading document. The PEW document simply fans the embers of the dying “global warming” alarm and, intended or not, misleads the public and policy makers at all levels.


[Claims by PEW are in italics, SPPI analysis and responses are standard type.]



¹ <http://www.pewclimate.org/docUploads/global-warming-science-brief-august08.pdf>


² <http://scienceandpublicpolicy.org/>

ANALYSIS AND RESPONSE

 **Pew:** *“During the twentieth century, the earth’s surface warmed by about 1.4°F. There are a variety of potential causes for global climate change, including both natural and human-induced mechanisms. Science has made great strides recently in determining which potential causes are actually responsible for the climate change that occurred during the twentieth century, providing strong evidence that greenhouse gases released to the atmosphere by human activities are the main cause of contemporary global warming.”*

SPPI: Pew has failed to point out several important inconsistencies and contradictions in its mere recitation of a selection of points taken from the IPCC’s 2007 assessment:

1. Not one of the computer models relied upon by the IPCC predicted that “global warming” would cease in 1998; that for seven years since late 2001 there would be rapid cooling; that the fall in temperatures between January 2007 and January 2008 would be the greatest since records began in 1880; and that the mean temperature for 2008 would be lower than the mean temperature for 1980, 28 years ago.
2. All of the models relied upon by the IPCC predict that, if anthropogenic greenhouse gases are the principal cause of “global warming”, then the rate of warming six miles up in the tropical mid-troposphere should be three times greater than the surface rate. However, half a century of radiosonde records and 30 years of satellite records do not show this tropical mid-troposphere “hot-spot”. The predicted fingerprint of anthropogenic “global warming” is entirely absent from the real-world observed record.
3. Graversen *et al.* (Nature, 2008) have shown that the pattern of observed surface and mid-troposphere warming in the Arctic is inconsistent with warming by the greenhouse effects of CO₂.
4. Henderson and Sellers (2008) and the World Meteorological Organization (2008) both express “real concern” about “serious inadequacies in climate change prediction” by computer models.

 **Pew:** *“Recent decades have seen record-high average global surface temperatures. Thermometer readings sufficient to provide reliable global averages are available back to 1850 (Brohan et al. 2006). In the past century, global*

surface temperature increased by about 1.4 °F (Fig. PEW 1). In the past quarter-century, according to satellite measurements, the lower atmosphere warmed by 0.22-0.34 °F per decade, equivalent to 2-3 °F per century (Christy and Spencer 2005; Mears and Wentz 2005). The past 20 years include the 18 warmest years on record (Hadley Centre 2005).”

SPPI: There has been no “global warming” in the 21st century, even though atmospheric CO₂ concentration continues to rise rapidly (Figure SPPI 1) The seven-year fall in global temperatures notwithstanding a continuing rise in carbon dioxide concentration seriously challenges the false notion that the Earth climate system is dominated by the radiative forcing arising from changes in CO₂ concentration, which was almost 20 times greater than today’s concentration during the Cambrian era and now occupies only one-ten-thousandth more of the atmosphere than it did in 1750. The total concentration of CO₂ in the atmosphere is less than 4 parts in 10,000.

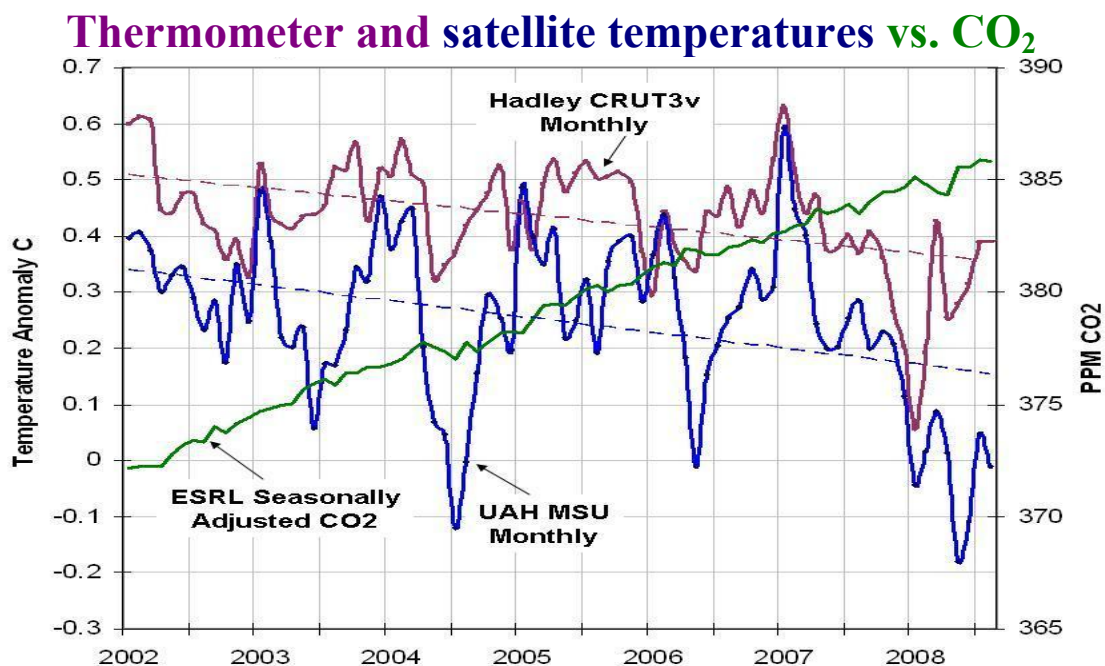


Figure SPPI 1. Source: Joe D’Aleo at <http://icecap.us>

Temperature records were not at all reliable before the satellite era that began not in 1850 but in 1979. Thermometer records from as far back as 1850 were not widespread enough or reliable enough for measuring global temperatures. Even today’s data quality from thermometer records is suspect: see Anthony Watts at <http://www.surfacestations.org> as well as important peer-reviewed scientific papers by deLaat and Maurellis (2006) and McKittrick and Michaels (2007).

De Laat and Maurellis (2006) found that –

“Over the last two decades non-GHG [Greenhouse Gases] anthropogenic processes have also contributed significantly to surface temperature changes. ... Our analysis of climate model simulations of GHG warming confirms our earlier results, namely, that they do not show any kind of CO₂ emission-temperature trend correlation. In fact, the modeled temperature trends are quite insensitive to the magnitude of the industrial CO₂ emissions.”

McKittrick and Michaels (2007) concluded that –

“Data contamination likely leads to an overstatement of actual [warming] trends over land. Using the regression model to filter extraneous, nonclimatic effects reduces the estimated 1980-2002 global average temperature trend over land by about half.”

Pew: This well-documented warming trend could result from several factors that influence the earth’s climate, some of which are natural, such as changes in solar radiation and volcanic activity. Others, particularly the release of certain gases to the atmosphere and land-cover changes, are man made. This brief describes recent scientific progress in identifying the causes. The greenhouse effect is a natural phenomenon whereby certain gases in the earth’s atmosphere, known as greenhouse gases, absorb heat that would otherwise escape to space.

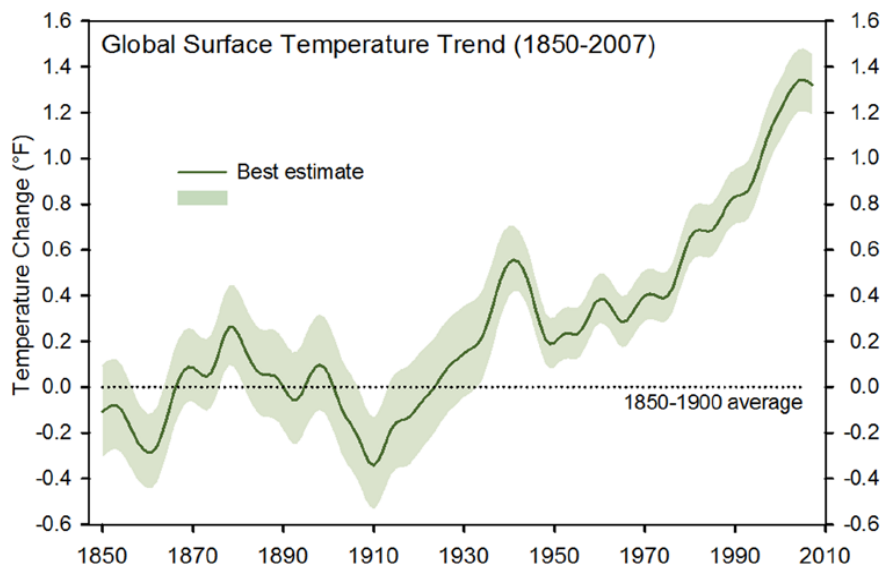


Figure Pew 1: Average global surface temperature based on instrumental measurements (Adapted from Brohan et al. 2006; © Crown copyright 2006, data supplied by the Met Office). Temperature rise during the twentieth century is much larger than the uncertainty range.

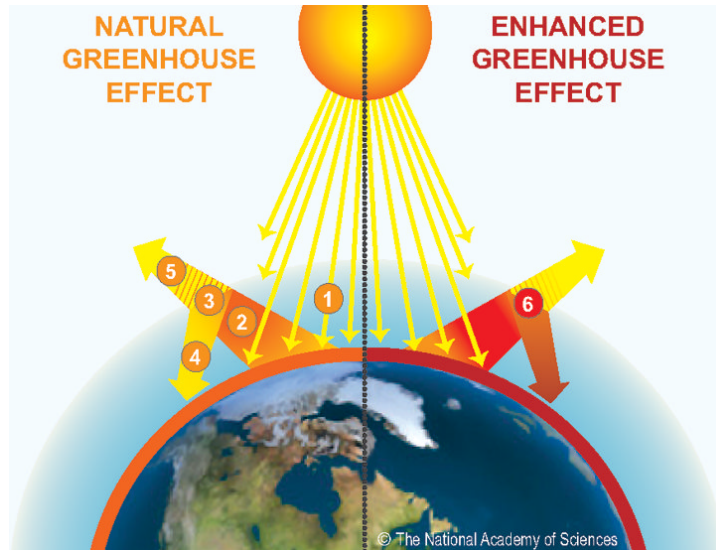


Figure Pew 2: Illustration of the greenhouse effect (Courtesy of the Marian Koshland Science Museum of the National Academy of Sciences). Visible sunlight passes through the atmosphere without being absorbed. Some of the sunlight striking the earth is (1) absorbed and converted to infrared radiation (heat), which warms the surface. The surface (2) emits infrared radiation to the atmosphere, where some of it (3) is absorbed by greenhouse gases and (4) re-emitted toward the surface; some of the infrared radiation is not trapped by greenhouse gases and (5) escapes into space. Human activities that emit additional greenhouse gases to the atmosphere (6) increase the amount of infrared radiation that gets absorbed before escaping to space, thus enhancing the greenhouse effect and amplifying the warming of the earth.

This heat originates from visible sunlight that warms the earth's surface. Subsequently, heat radiates from the surface to the atmosphere, where some of it is absorbed by greenhouse gases and radiated back to the surface (Figure Pew 2). Recent progress in climate modeling has generated a consensus among climate scientists that greenhouse gases emitted by human activities are likely (66-90% chance) to have caused most of the observed global temperature rise over the past 50 years (Mitchell et al. 2001). The increase in the strength of the greenhouse effect as a result of man-made greenhouse gases is known as the enhanced greenhouse effect.

Factors that Influence Global Temperature

Global climate varies over time in response to climate forcings—physical factors external to the climate system that force a net increase (positive forcing) or net decrease (negative forcing) of heat in the climate system as a whole (Hansen, Sato et al. 2005). This type of change is distinct from internal climate variability, in which heat is transported by winds or ocean currents between different components of the climate system with no net change in the total heat within the system. The El Niño–Southern Oscillation is a well-known example of internal climate variability. Because the observed climate change over the twentieth century results from a net increase of heat in the entire climate system, it can only be explained by external forcing (Hansen, Nazarenko et al. 2005). Hence, the task for climate change scientists is to identify one

or more external forcing(s)—natural or man made—that can explain the observed warming.

SPPI: The discussion here on “heat” imbalances and climate forcings to within one or two watts per square meter (W/m^2), with the reference to Hansen, Nazarenko et al. (2005) on the “smoking gun” evidence from the anthropogenic CO_2 forcing found in the ocean heat storage data records requires some historical and physical clarification.

First, as far back as 1985, Hansen and his colleagues had published a notion of “heat” storage in the ocean or “warming in the pipeline”. Hansen’s political intention in inventing this notion was to pre-empt the correct policy response: namely, to wait and see whether and to what extent “global warming” will actually occur and whether, if it does occur, its effects will be sufficiently significant or even harmful to require any political action at all. As Hansen’s 1985 paper revealingly put it –

“This yet-to-be-realized warming calls into question a policy of ‘wait and see’ regarding the issue of how to deal with increasing atmospheric carbon dioxide and other trace gases.”

Now, Hansen *et al.* are claiming to see or detect a net heat imbalance of “ $0.85 \pm 0.15 W/m^2$ ” absorbed in the world’s oceans. They continue –

“This imbalance is confirmed by precise measurements of increasing ocean heat content over the past 10 years. Implications include (i) the expectation of additional global warming of about $0.6^\circ C$ without further change of atmospheric composition; (ii) the confirmation of the climate system’s lag in responding to forcings, implying the need for anticipatory actions to avoid any specified level of climate change and (iii) the likelihood of acceleration of ice sheet disintegration and sea level rise.”

Recent papers (e.g. Willis *et al.*, 2008) have firmly put paid to the notion that the heat content of the ocean can be represented by “precise measurements”. There have been too many changes in the methods of measurement; too many unreliabilities in the technology; too few measurements, particularly at depth. There is simply no credible scientific basis for Hansen’s detection of an imagined “net heat imbalance”, still less for the elaborate edifice of alarmism that has been built upon it.

How much, then, is the ocean really warming? Gouretski and Koltermann (2007) consider this question. Figure SPPI 2 clearly shows that poor statistical sampling of the world's oceans and the great difficulties in obtaining reliable data on ocean heat energy measured – as it should be – in Joules (for example, see Professor Roger Pielke Sr., August 5, 2008, <http://climatesci.org/2008/08/05/monitoring-upper-ocean-heat-content-in-real-time> on the need to obtain absolute heat-energy figures before attempting to determine changes in the *flux* of energy to or from the oceans) does not allow us to assume that the “heat imbalance” imagined by Hansen *et al.* exists at all, let alone that we can quantify it to the nearest hundredth of a Watt per square meter.

Gouretski and Koltermann conclude that –

“Our estimate of the ocean heat content increase (0-3000 m) between 1957-66 and 1987-96 is 12.8×10^{22} Joules. Because of imperfect sampling this estimate has an uncertainty of at least 8×10^{22} J.”

In short, there has been no clear detection of additional heat storage in the world's oceans. Hansen's result is imagined, not real: hoped for, but not definitively measured.

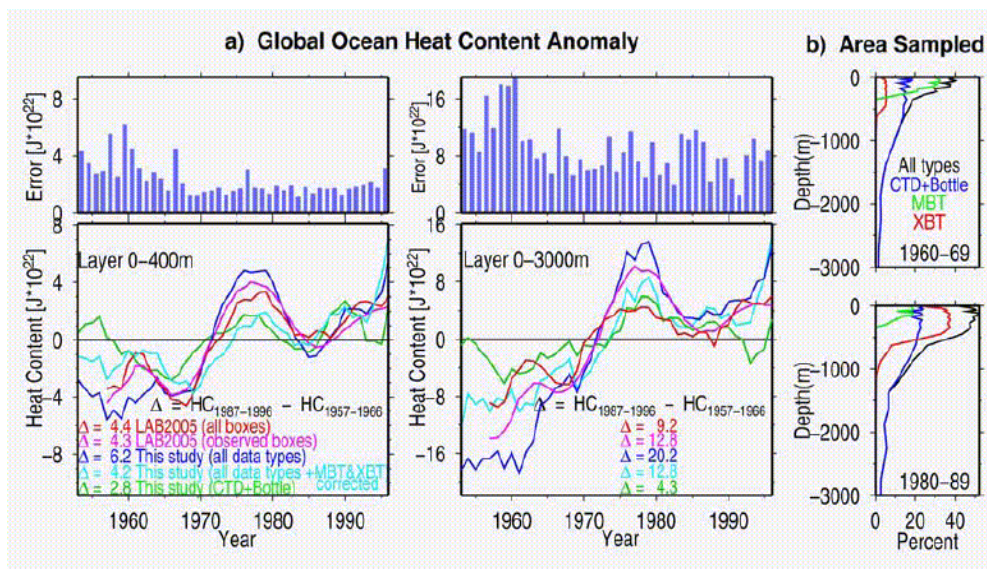


Figure SPPI 2: There are very large errors in estimating the heat content of the oceans, and demonstrates that at depth most of the oceans have not been measured at all. Source: Gouretski & Koltermann (2007).

Zooming in on the most recent interval from July 2003 till January 2008 where world ocean heat content can be deduced from *in-situ* ocean measurements, Figure SPPI 2b offers the preliminary result from Josh Willis of NASA JPL (obtained from the May 29, 2008 web-blog by Roger Pielke Sr.): Once again, the error bars are so large that the indication of a slight decreasing ocean heat content trend is probably not statistically significant.

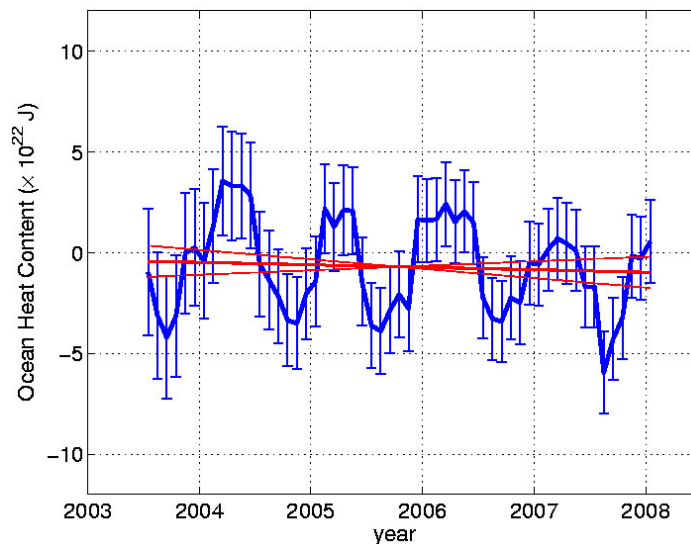


Figure SPPI 2b: Large errors in estimating the heat content of the ocean from July 2003 to January 2008: Error bars shown are for one standard deviation values. Source: Willis et al. (2008) from <http://climatesci.org/2008/05/29/new-information-from-josh-willis-on-upper-ocean-heat-content>

If the real-world data do not permit a proper quantification of changes in ocean heat storage, can the theoretical world of the General Circulation climate models relied upon in the IPCC's 2007 climate assessment or in the third phase of the Coupled Model Intercomparison Project (CMIP3) do any better?

The answer is not helpful for the Pew Center's seemingly scientific but actually political agenda. For example, Wild (2008) recently concluded that –

“Compared to a comprehensive set of surface observations, a long-standing problem continues to appear in the IPCC-AR4/CMIP3 models: the models still show an overall tendency to overestimate the downward solar radiation and underestimate the downward long-wave radiation at the surface by +6 and -5.6 W/m², respectively, on average over all models. ... The tendency for excessive downward solar radiation and, at the same time, lack of

downward long-wave radiation often found in GCMs have lead over many years to a superficially correct simulation of surface net radiation due to error cancellation, as pointed out in Wild et al. (1995, 1998a). ”

Recall that Hansen says he can detect “ $0.85 \pm 0.15 \text{ W/m}^2$ ” of net heat storage in the oceans by using computer climate models. Yet the models used by the IPCC – and Hansen’s is one of them – are incapable of evaluating net surface radiation correctly except by the accident of mutual cancellation of two very large errors. Finally, Pielke Sr. (December 17 2007: <http://climatesci.org/2007/12/17/reality-check-2-long-term-sea-surface-temperature-trend-anomalies-and-ocean-heat-content-trends/>) have published updated information on global sea surface temperature and ocean heat content trends that simply do not suggest a continuing warming tendency. Instead, they suggest a noticeable cooling of the oceans over the past four years.

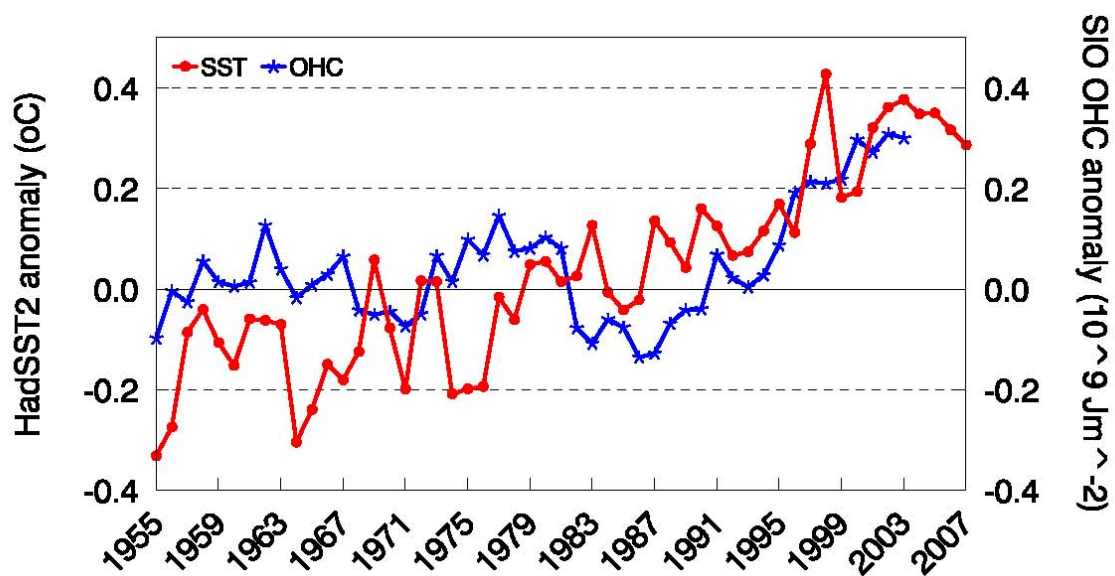


Figure SPPI 3: Departures from the 1961-1990 mean in annual sea surface temperatures and ocean heat content in the upper 300 m of the oceans. Sea surface temperatures for 2007 are estimated by averaging to September of that year.

Since the Pew Center also mentions the El Nino Southern Oscillation (ENSO) as a well-known example of “internal climate variability”, how well can computer models simulate how El Ninos change in response to increasing atmospheric CO₂?

Merryfield (2006) in a comprehensive analysis/review of IPCC AR4 models found that –


“Under preindustrial conditions [with no CO₂ climate forcing and the 1860 AD atmospheric CO₂ value of 288 ppm used], 12 of the 15 models exhibit ENSO amplitudes comparable to or exceeding that observed in the second half of the twentieth century. [NB: So the seeming “agreement” is largely fortuitous!] ... Under CO₂ doubling, 8 of the 15 models exhibit ENSO amplitude changes that significantly ($p < 0.1$) exceed centennial time scale variability within respective control runs. However, in five of these models the amplitude decreases whereas in three it increases; hence there is no consensus as to the sign of change. ... The overall amplitude changes are not strongly related to the magnitude or pattern of surface warming.”

An et al. (2008) further noted that –

“Collins (2000a) [had earlier] found that a subtle change in the physical parameterization schemes caused a significant difference in the statistics of ENSO response to the greenhouse warming. Due to a lack of consistency in model results on ENSO response to the greenhouse warming, the predictability of future ENSO activity is very limited so far.”

Kucharski et al. 2008 considered whether “global warming” could influence Indian monsoons, and answered No –

“Using a selection of control integrations from the World Climate Research Programme’s (WCRP’s) Coupled Model Intercomparison Project phase 3 (CMIP3), it is shown that the increase of greenhouse gases (GHG) in the twentieth century has not significantly contributed to the observed decadal IMR [Indian Monsoon Rainfall] variability.”

 *Pew: Until recent centuries, climate forcings were exclusively natural, such as changes in the amount of sunlight reaching the earth’s surface and changes in emissions of dust from volcanoes. During modern times, human activities have introduced a mix of additional forcings, such as increases in atmospheric greenhouse gases that cause warming (positive forcing), and sulfate aerosols, miniscule particles that reflect sunlight and cause cooling (negative forcing). The histories and magnitudes of various forcings are estimated from direct observations, such as satellite measurements of solar radiation in recent decades, or from proxies, such as sunspots for solar radiation in earlier decades (Foukal et al. 2004). The histories of individual forcings (Fig. PEW 3) are then examined for the potential to cause the observed pattern of climate change (Hansen, Sato et al. 2005). Scientists employ records of*

various forcings in a fingerprinting approach to identify which forcings can account for observed patterns of climate change (e.g., Santer et al. 2004).

A particular forcing imprints itself uniquely on the past climate record based on how the forcing works and how its strength varies through space and time (e.g., Santer et al. 2004; Barnett et al. 2005). For example, volcanic eruptions cause short-term, sudden cooling. Changes in solar radiation cause warming of the lower and upper atmosphere, and follow the 11-year cycle of solar variability. Changes in greenhouse gases cause greater warming over land than oceans and warm the lower atmosphere but cool the upper atmosphere. Sulfate aerosols cause cooling that is strongest over industrialized regions. These idiosyncrasies of particular external forcings allow scientists to detect the fingerprints of particular forcings in records of observed climate change.

SPPI: Let us focus on the so-called “fingerprints” from increasing greenhouse gases and CO₂. The Pew Center says that land has greater warming than ocean. However, here is the latest scientific research published in the peer-reviewed journal *Climate Dynamics* by Compo and Sardeshmukh (2008) –

“Evidence is presented that the recent worldwide land warming has occurred largely in response to a worldwide warming of the oceans rather than as a direct response to increasing greenhouse gases (GHGs) over land. Atmospheric model simulations of the last half-century with prescribed observed ocean temperature changes, but without prescribed GHG changes, account for most of the land warming.”

Is ocean warming caused by increasing greenhouse-gas concentrations at all? Compo and Sardeshmukh (2008) say –

“Several recent studies suggest that the observed SST [sea surface temperature] variability may be misrepresented in the coupled models used in preparing the IPCC’s Fourth Assessment Report, with substantial errors on interannual and decadal scales (e.g., Shukla et al. 2006; DelSole 2006; Newman 2007; Newman et al. 2008). There is a hint of an underestimation of simulated decadal SST variability even in the published IPCC Report (Hegerl et al. 2007, FAQ9.2, Fig. 1). Given these and other misrepresentations of natural oceanic variability on decadal scales (e.g., Zhang and McPhaden 2006), a role for natural causes of at least some of the recent oceanic warming should not be ruled out.”

The Pew Center says atmospheric CO₂ warms the lower atmosphere but cools the upper atmosphere. However, Figure SPPI 4, from the recently published paper by Kodera et al. (2008), tells the fuller story –

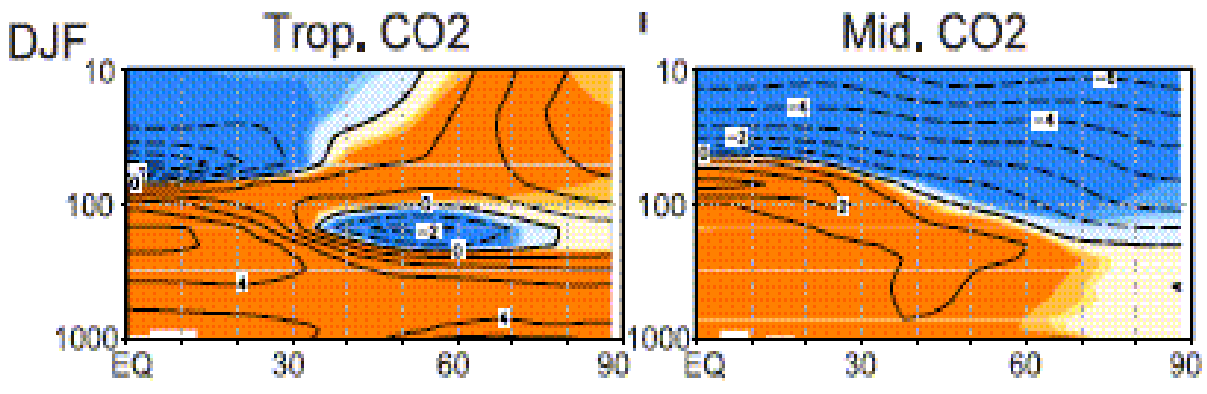


Figure SPPI 4: Modeled atmospheric temperature change in the northern-hemisphere winter if CO₂ content is doubled within the troposphere only (left panel), and within the middle atmosphere including both stratosphere and mesosphere (right panel).

Figure SPPI 4 suggests that even if we consider atmospheric CO₂ change alone, the temperature responses are complicated, with no easy way to “fingerprint” the distinction between the effects occurring in the troposphere and those in the stratosphere as simplistically argued by the Pew Center. In the left panel, for example, note the cooling patch from 35-80°N in the mid/upper troposphere (400-100 mb; about 9-16 km) or the warming patch from 50-90°N in the upper atmosphere (200-10 mb; about 11-30 km) in response to doubling tropospheric CO₂. Despite the complex patterns of atmospheric temperature response, one consistent response feature is pointed out by Kodera et al. (2008) –

“Increasing CO₂ in the troposphere warms the troposphere and cools the lower stratosphere in the equatorial region due to stronger upward motion.”

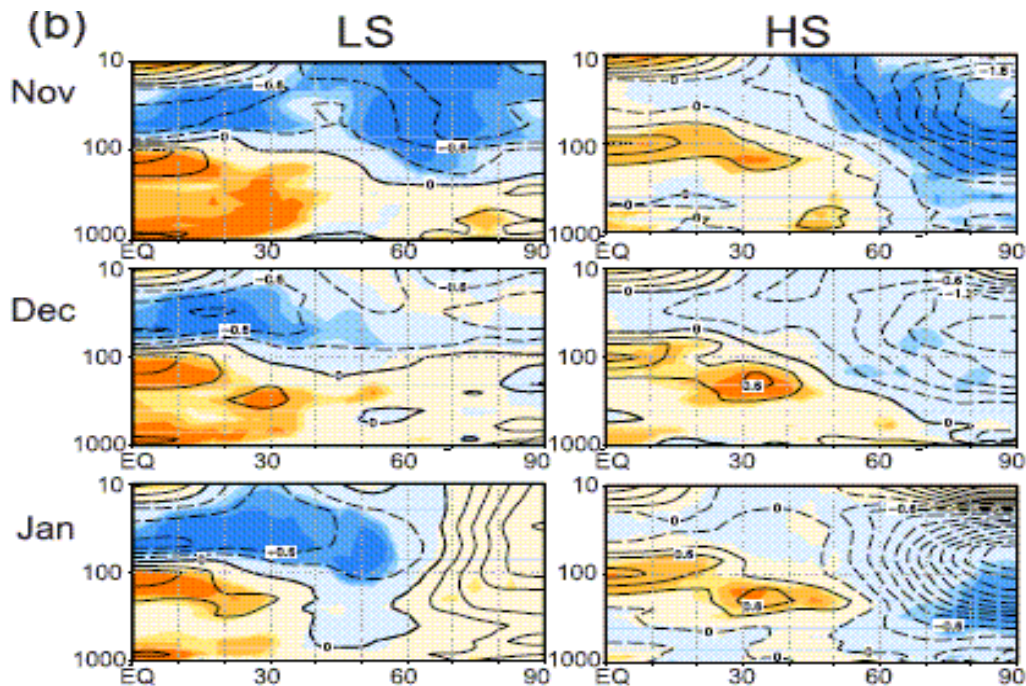


Figure SPPI 5, showing trend values in units of 0.3 °C/decade, demonstrates that within the tropical troposphere and stratosphere the Northern-Hemisphere winter temperature trends from 1958-2005 suggest a fingerprint of response to changes in solar activity rather than the CO₂-forced fingerprint described by Koder et al. (2008). Although the quality of the atmospheric temperature data suffers from sparse statistical sampling, the warm spot in the middle and upper tropical stratosphere (equator-30°N and 30-10 mb; about 24-30 km), regardless of the level of solar activity, contradicts the predicted large tropical cooling trend in the middle-upper stratosphere and mesosphere from increasing atmospheric CO₂ concentration.

SPPI: Additional Readings in Climate Science

Environmental Effects of Increased Atmospheric Carbon Dioxide
<http://scienceandpublicpolicy.org/other/increasedco2effects.html>

35 Inconvenient Truths: The errors in Al Gore's movie
<http://scienceandpublicpolicy.org/monckton/goreerrors.html>

Hockey Stick? What Hockey Stick?
http://scienceandpublicpolicy.org/monckton/what_hockey_stick.html

Letter to Senator McCain
http://scienceandpublicpolicy.org/reprint/letter_to_mccain.html

Sherwood and Craig Idso examine James Hansen's Senate testimony.
http://scienceandpublicpolicy.org/other/sherwood_and_craig_idso_examine_james_hansen_s_recent_senate_testimony.html



Modeling to Identify Causes of Climate Change

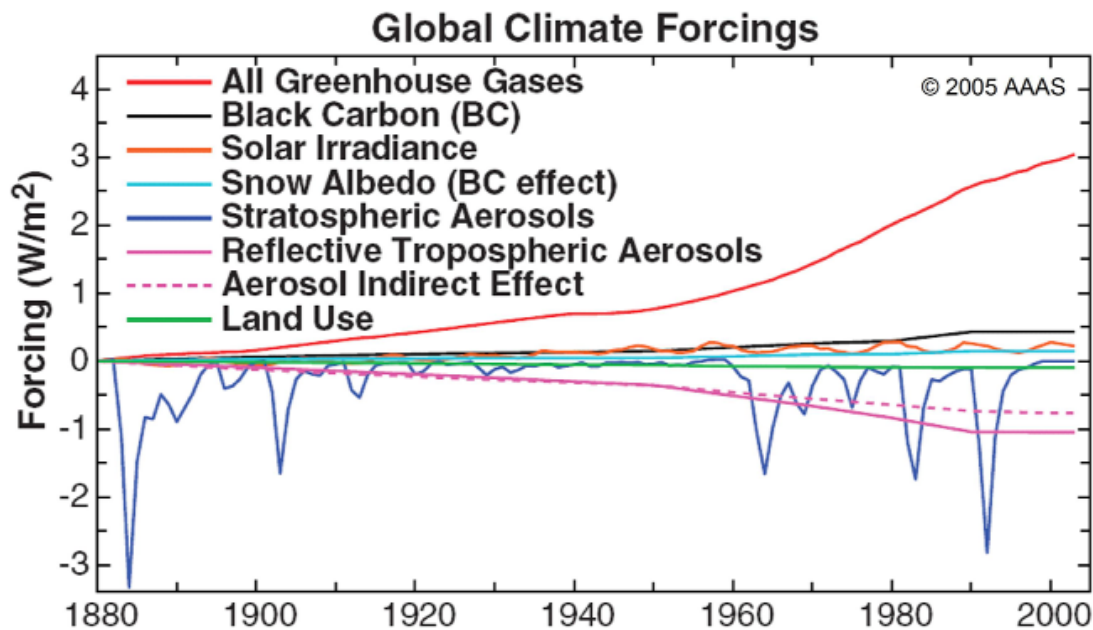


Figure Pew 3: Forcings used to drive global climate simulations (From Hansen, Sato et al. 2005; Reprinted with permission from AAAS). Records of forcing history are compiled from a wide variety of direct observations and proxies. Each forcing has a unique historical pattern that serves as its fingerprint of influence on observed climate change. Positive forcings exert a net warming effect (e.g., greenhouse gases, red line), whereas negative forcings exert a net cooling effect (e.g., stratospheric aerosols from volcanic eruptions, dark blue line). Greenhouse gases exhibit the largest trend of all forcings shown.

Pew: Fingerprint matching between climate forcings and observed climate change is performed using physical climate models that calculate how each forcing should have affected climate over time, based on its history and how scientists understand the physical mechanisms of each forcing. These models are able to reproduce most of the major features of the global climate system, including the pattern of global warming over the past century (e.g., Stott et al. 2000).

The models serve as controlled experiments that test alternative hypotheses about the causes of climate change. Each forcing depicted in Fig. PEW 3 represents a hypothesized cause of observed climate change. Entering records of one or more forcings into a model, scientists assess whether the climate scenario generated by the model is similar to the observed climate record; no observed climate data are entered into the model. If the simulated climate matches observed climate, then the forcing(s) represented in the model can explain the observed climate record. If not, the forcing(s) cannot explain the observed climate change. Of course, it is possible that more than one forcing is involved, so scientists test all possible combinations of forcings to see if their combined influence can explain observed climate change (e.g. Meehl et al. 2004).

Independent modeling of different components of the climate system demonstrates that man-made greenhouse gases have been the dominant forcing of climate change over

the past half-century. The distinct fingerprint of man-made greenhouse gases has been detected in records of surface temperature, ocean heat content, and the vertical structure of the atmosphere above the earth's surface.

SPPI: Computer climate models have not performed as well as the Pew Center suggests in identifying physical processes and predicting societal impacts. Most climate science research funding should probably be stopped in order to allow for funding of more urgent priorities like research into cancer and childhood diseases.

Henderson-Sellers (2008), the former Director of the World Climate Research Programme of the WMO, recently said that certain anonymous but “eminent” IPCC AR4 Report authors have given warnings that –

- “Progress requires more attention to addressing basic model flaws. Without alleviating these, future IPCC assessments will look very similar each time. What a waste of resources ... climate science will get what it deserves if it does not apply itself more to basics rather than what it is doing currently.
- “Adding complexity to models, when some basic elements are not working right (e.g. the hydrological cycle) is not sound science. A hierarchy of models can help in this regard.
- “Until and unless major oscillations in the Earth System [El Nino-Southern Oscillation (ENSO), Pacific Decadal Oscillation (PDO), North Atlantic Oscillation (NAO) and Atlantic Multidecadal Oscillation (AMO) etc.] can be predicted to the extent that they are predictable, regional climate is not a well defined problem. It may never be. If that is the case then we should say so. It is not only the forecast but the confidence and uncertainty that are just as much a key.”

Surface warming



Pew: The twentieth-century warming trend at the earth's surface progressed in a distinct pattern, with a large warming during 1910-1940, moderate cooling during 1940-1975, and a large warming from 1975 to the present (Fig. PEW 1). Scientists at the National Center for Atmospheric Research (NCAR) looked for fingerprints of various natural (solar radiation, volcanic particles) and man-made (greenhouse gases, sulfate aerosols) forcings in this record of observed climate change (Meehl et al. 2004). The study employed a physical climate model that allowed individual or combinations of forcings to drive the simulated climate. The change in surface temperature calculated by the model for each forcing or combination of forcings was then compared with the observed record of surface temperature change over the twentieth century (Fig. PEW 4).

The best fit of the model results to the observed climate was produced when all of the forcings were included, implicating all of the forcings in producing the overall pattern of change (Fig. PEW 4A). However, different forcings dominated at different times during the century (Takemura et al. 2006). For instance, the temperature rise in the early part of the century was dominated by natural forcings (Fig. PEW 4B), whereas the warming after 1975 was dominated by man-made greenhouse gases (Fig. PEW 4C). The cooling during the mid-century was consistent with a combination of natural volcanic and man-made aerosols (Nagashima et al. 2006).

The results of this study implicate the enhanced greenhouse effect as the dominant cause of global warming over the past three decades. If not for the temporary cooling between 1940 and 1975 from volcanic and man-made aerosol emissions, the earth might be even warmer than it is today (Mitchell et al. 2001).

SPPI: Additional Readings on the IPCC

The IPCC report: What the lead authors really think

http://scienceandpublicpolicy.org/reprint/sellers_ipcc_report.html

Prejudiced Authors, Prejudiced Findings

http://scienceandpublicpolicy.org/originals/prejudiced_authors_prejudiced_findings.html

Peer review? What peer review?

http://scienceandpublicpolicy.org/sppi_originals/peerreview.html

What is Wrong with the IPCC?

<http://scienceandpublicpolicy.org/reprint/whatiswrongwiththeipcc.html>

On The IPCC's Case For Anthropogenic Global Warming

http://scienceandpublicpolicy.org/commentaries_essays/ipcc_s_case_for_anthropogenic_global_warming.html

The IPCC: On the Run at Last

http://scienceandpublicpolicy.org/reprint/ipcc_on_the_run.html

Open Letter to the Secretary-General of the United Nations

http://scienceandpublicpolicy.org/reprint/open_letter_to_un.html

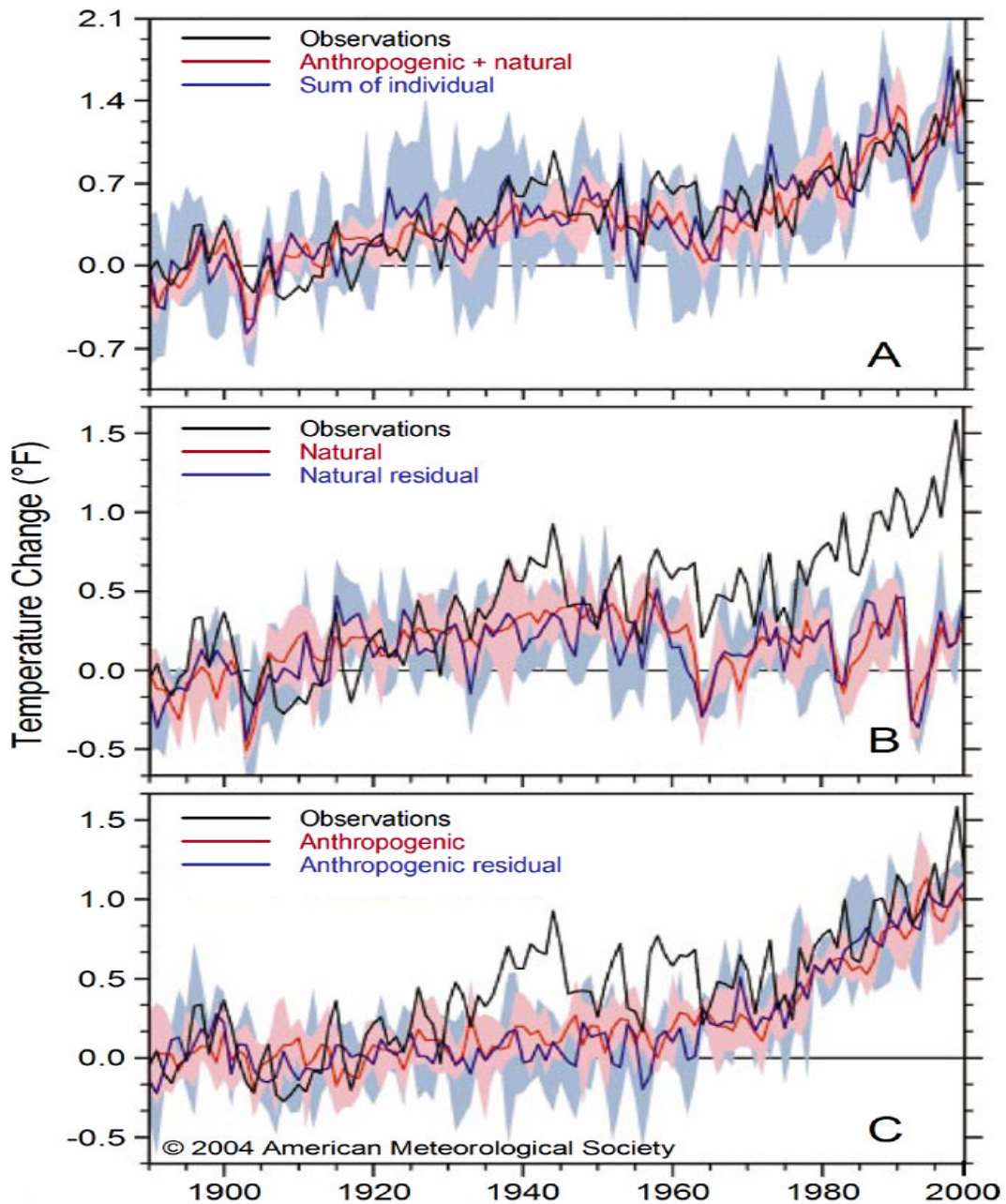


Figure Pew 4: Fingerprint-modeling of global surface temperature change (adapted from Meehl et al., 2004). (A) Model results with all forcings included. The combined forcings provided the best match to the fingerprint of climate change in the observed record. (B) Natural forcings alone explained much of the temperature change in the first half of the century. (C) Man-made forcings strongly dominated the temperature change after 1975.

SPPI: Here, the Pew Center is short-sightedly promoting the mere curve-fitting exercise in Fig. Pew 4 as being some sort of scientific trophy supporting the role of anthropogenic greenhouse gases. The intent is clear:

“The results of this study implicate the enhanced greenhouse effect as the dominant [our emphasis] cause of global warming over the past three decades.”

However, it is not as simple as that. Knutti (2008), an IPCC lead author, says –

“The iconic figure showing agreement between simulated and observed global temperature over the 20th century *should not* [our emphasis] be interpreted itself as the attribution of anthropogenic influence on climate. Just because we can build a model that replicates 20th century global temperature (and nothing else) doesn’t imply that the model is correct. ...

“Climate models reproduce the observed surface warming better than one would expect given the uncertainties in radiative forcing, climate sensitivity and ocean heat uptake, suggesting that different models show similar warming for different reasons. It is shown that while climate sensitivity and radiative forcing are indeed correlated across the latest ensemble of models, eliminating this correlation would not strongly change the uncertainty range of long-term temperature projections. However, since most models do not incorporate the aerosol indirect effects, model agreement with observations may be partly spurious. The incorporation of more detailed aerosol effects in future models could lead to inconsistencies between simulated and observed past warming, unless the effects are small or compensated by additional forcings.”

Ocean heat content

Pew: Oceans exhibit natural temperature cycles, with some oceans cooling at the same time that others warm. This natural internal variability of climate results from heat transport from one place to another, but it adds no new heat to the ocean as a whole. A major challenge for assigning a cause to temperature changes is distinguishing internal variability from external forcing, which adds new heat to the system.

Recently, scientists from the U.S. National Oceanographic and Atmospheric Administration demonstrated that the ocean as a whole has been warming for the past five decades (Levitus et al. 2005). The first principles of physics dictate that simultaneous warming of all the world’s oceans could only occur through external forcing, as there is no other source of this much energy within the climate system (Hansen, Nazarenko et al. 2005).

Using a fingerprinting-modeling approach similar to the one described above, scientists at Scripps Institution of Oceanography, Lawrence Livermore National Lab, NCAR, and the United Kingdom's Hadley Center, published a study showing that the oceans situated along the equator have warmed over the past five decades as a direct result of the enhanced greenhouse effect (Barnett et al. 2005).

Observations show that the oceans have been warming from the surface downward (red dots, Fig. PEW 5), which indicates heat transfer from the atmosphere. The vertical pattern of heat penetration with depth varies from ocean to ocean as a result of internal variability (i.e. currents transporting heat from one ocean to another).

This complex pattern of vertical profiles provides a “fingerprint” of climate forcing. Modeling of internal variability alone or internal variability combined with solar and volcanic forcings did not produce temperature profiles that matched this fingerprint (Fig. Pew 5A). However, the combined influence of human-induced forcings, natural forcings, and internal variability reproduced the pattern of heat penetration for each ocean (Fig. Pew 5B). Man-made greenhouse gases strongly dominated the overall forcing.

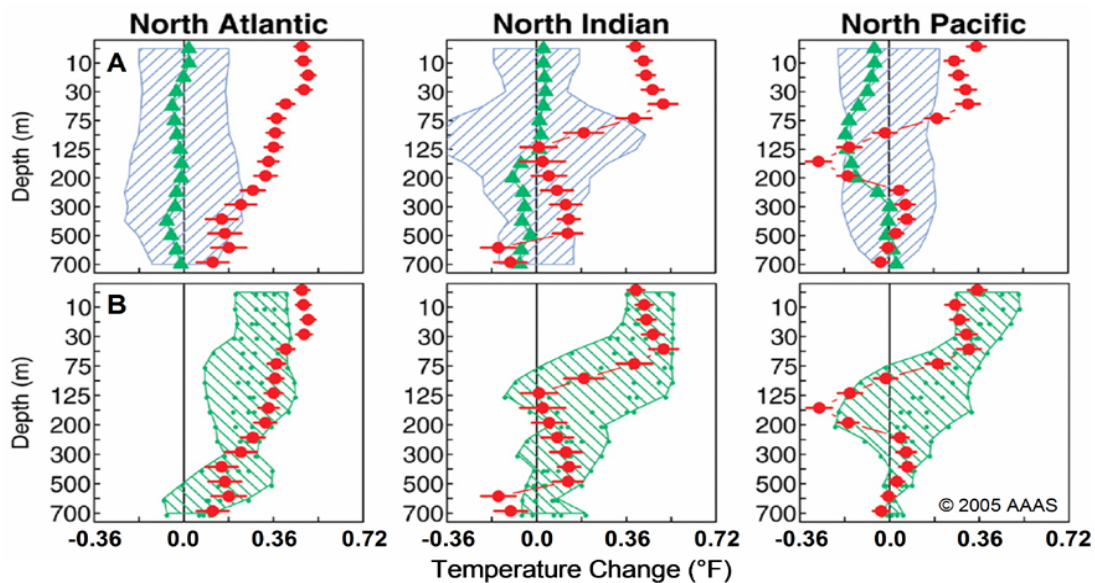


Figure PEW 5: Observed and simulated heat penetration into three ocean basins (Adapted from Barnett et al. 2005; Reprinted with permission from AAAS). (A) The blue hatched region represents the 90% confidence limits of modeled natural internal variability resulting from heat exchange among different ocean basins. The observed record of temperature change (red dots) bears little resemblance to that expected from internal variability. The strength of the warming trend forced by observed solar and volcanic variability (green triangles) shows little agreement with the observed climate trend. (B) The modeled human-induced forcing from greenhouse gases and sulfate aerosols (green hatched region) shows substantial fingerprint matching with the observed heat penetration (red dots).

SPPI: Again, it is not as simple as that. First, from the discussion above about (1) the great current difficulties of obtaining reliable ocean heat content data, such

those carefully assembled and discussed by Gouretski and Koltermann (2007), and (2) the major problems in accounting for all the meteorological and climatic processes in a computer climate model, one should be immediately suspicious of the spectacular agreement noted by the Pew Center.

Secondly, compare Figure Pew 5B, from Barnett *et al.* (2005), with SPPI Chart 6, a comparison between observations and the model-predicted anthropogenic signal for the North Pacific basin using the outputs from the U.K.'s Hadley Centre Model –

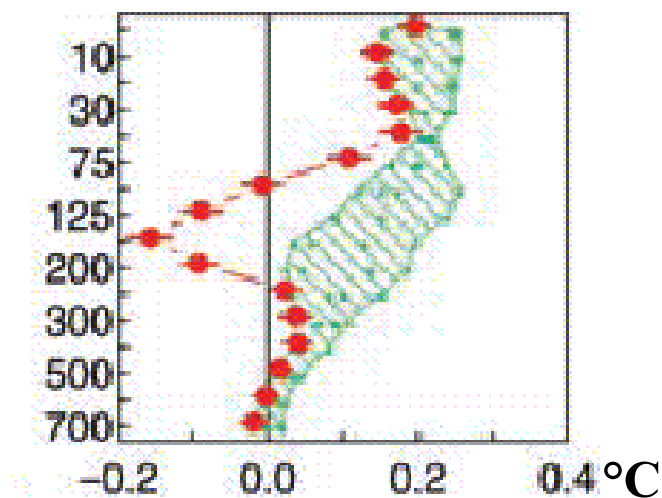


Figure SPPI 6: Observed and simulated heat penetration in the North Pacific basin, from the Parallel Climate Model at the US National Center for Atmospheric Research.

The NCAR model provides a far less close fit than the Hadley model. It is not credible, therefore, to claim – as the Pew Center too readily claims – that the fit between models and theory is precise and compelling.

Thirdly, without even going into the complexities of subsurface ocean temperature and heat content data, Compo and Sardeshmukh (2008b), forcefully describe need to remove variations related to el Nino Southern Oscillations from sea surface temperature records –

“Regardless of the relative magnitudes of the potentially predictable ‘forced’ and unpredictable ‘low-frequency tail’ portions of our estimated ENSO-related variations, the very existence of an unpredictable portions makes it inappropriate to compare climate model simulations of SST variations over the last 136 years with the observed SSTs variations.”

Fourthly, key information was omitted from the discussion of Fig. Pew 5 (perhaps because it was also omitted from the source paper, Barnett *et al.*, 2005). That information was actively emphasized in Levitus *et al.* (2005), the paper that had provided the 1955-2003 ocean data relied upon by Barnett:

“One dominant feature of the curves in Figure 1 is the large decrease in ocean heat content beginning around 1980. The 0-700 m layer exhibits a decrease of approximately 6×10^{22} Joules between 1980 and 1983. This corresponds to a cooling rate of 1.2 W/m^2 (per unit area of Earth’s total surface). Most of this decrease occurs in the Pacific Ocean. ... [T]he large decrease in ocean heat content starting around 1980 suggests that internal variability of the Earth system significantly affects Earth’s heat balance on decadal timescales.”

The influence of internal climate variability, rather than external climate forcings such as those from greenhouse gases, is confirmed graphically in Figure SPPI 7 –

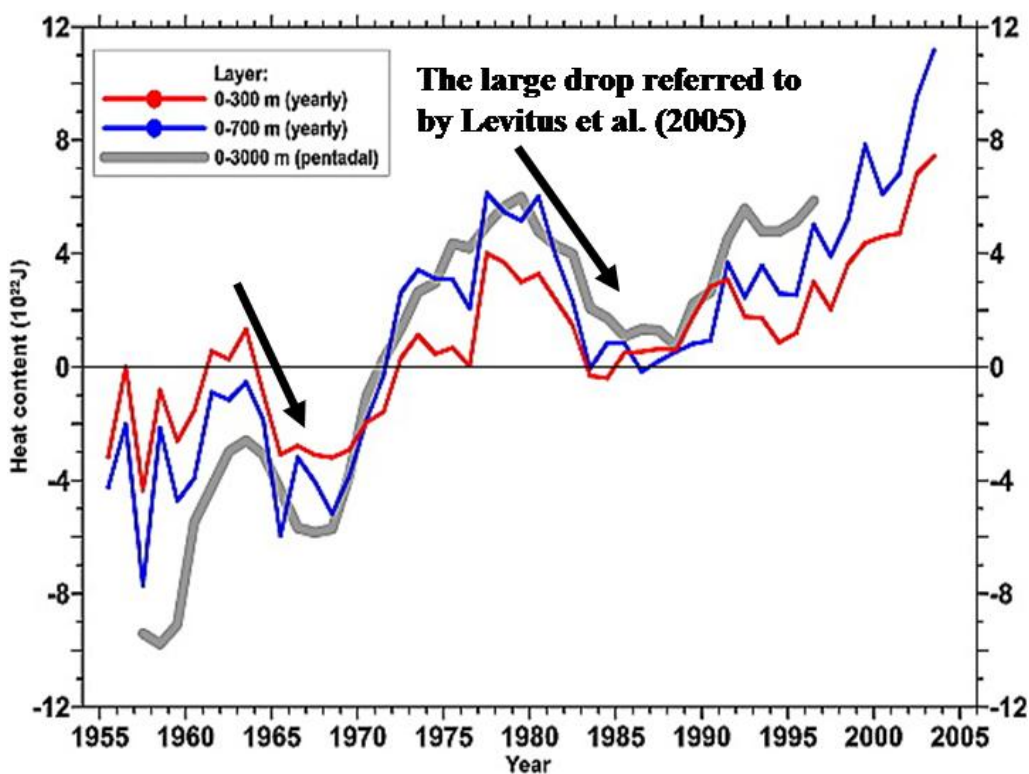


Figure SPPI 7: The sharp fluctuations in ocean heat content shown in Figure 1 of Levitus et al. (2005).

Finally, as An et al (2008), in a careful study of changes in El Nino Southern Oscillations in response to increasing atmospheric CO₂ forcing, noted that observed ocean subsurface temperature trends probably resulted from dynamical adjustment to persisting natural processes that had been initiated years to decades ago –

“In most of the scenario runs, the tropical ocean surface temperature responds to greenhouse warming linearly and simultaneously. ... On the other hand, radiative forcing [by the atmospheric CO₂ greenhouse effect] hardly reaches the ocean subsurface level; thus, the increase of greenhouse gases only indirectly influences the subsurface temperature through the dynamical advective processes. While the subsurface temperature in the equatorial eastern Pacific may be determined by meridional thermal advection by the subtropical-tropical oceanic overturning cell, zonal thermal advection in the tropical Pacific, thermal diffusion, and so on ... The point made by this study is that, because the subsurface temperature is determined by ocean dynamical process, a significant delayed response of the subsurface temperature to the increasing greenhouse gases should be expected.”



Vertical structure of the atmosphere

Pew: Another fingerprint of the enhanced greenhouse effect has been identified in the observed increase in the height of the tropopause, a region of the earth's atmosphere that represents the transition between the lower atmosphere (troposphere) and the upper atmosphere (stratosphere). Factors that either warm the troposphere or cool the stratosphere increase the tropopause elevation (Fig. Pew 6), and climate models have long predicted that the elevation of the tropopause above the earth's surface should increase as a result of the enhanced greenhouse effect (Santer et al. 2003). Although this phenomenon may affect climate behavior, it is discussed here strictly as a tool for identifying causes of observed climate change.

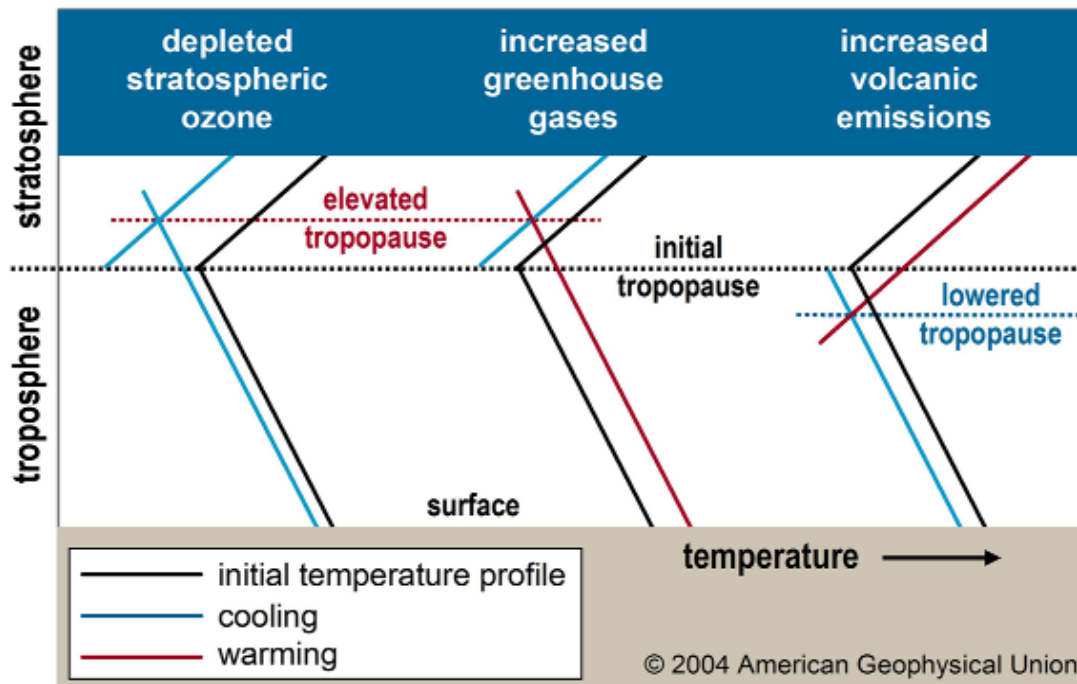


Figure Pew 6: Conceptual model for the effects of three different forcings on tropopause height (Adapted from Santer et al. 2004). The solid black lines are the baseline atmospheric temperature profiles. Forcing by either stratospheric ozone depletion or increases in well-mixed atmospheric greenhouse gases increase tropopause height; volcanic forcing decreases tropopause height.

Scientists from several American, British, and German research institutions employed a fingerprinting-modeling approach to determine which climate forcings could explain observed changes in the height of the tropopause (Santer et al. 2003; Santer et al. 2004). Between 1979 and 2001, satellites monitoring the atmosphere recorded a 620-foot rise of the tropopause. In the model simulations forced by both natural and human-induced forcings, the tropopause elevation increased similarly (Fig. PEW 7A). Man-made greenhouse gases, which warmed the troposphere, and stratospheric ozone depletion (by manmade chemicals), which cooled the stratosphere, dominated the forcing. Man-made greenhouse gases caused about 40 percent of the rise (Fig. PEW 7B, green line), whereas ozone depletion caused about 60 percent (Fig. PEW 7B, purple line). Overall, the effect of solar forcing, which contributed slightly (less than 10%) to the rise of the tropopause, was canceled by a small negative forcing (decrease in tropopause height) from volcanoes (Fig. PEW 7B, gray line; note the transitory decreases corresponding to the eruptions of the Agung, El Chichón, and Pinatubo volcanoes). Thus, human-induced forcings from greenhouse gases and ozone-depleting chemicals provide the best explanation for the observed increase in the elevation of the tropopause over the past few decades.

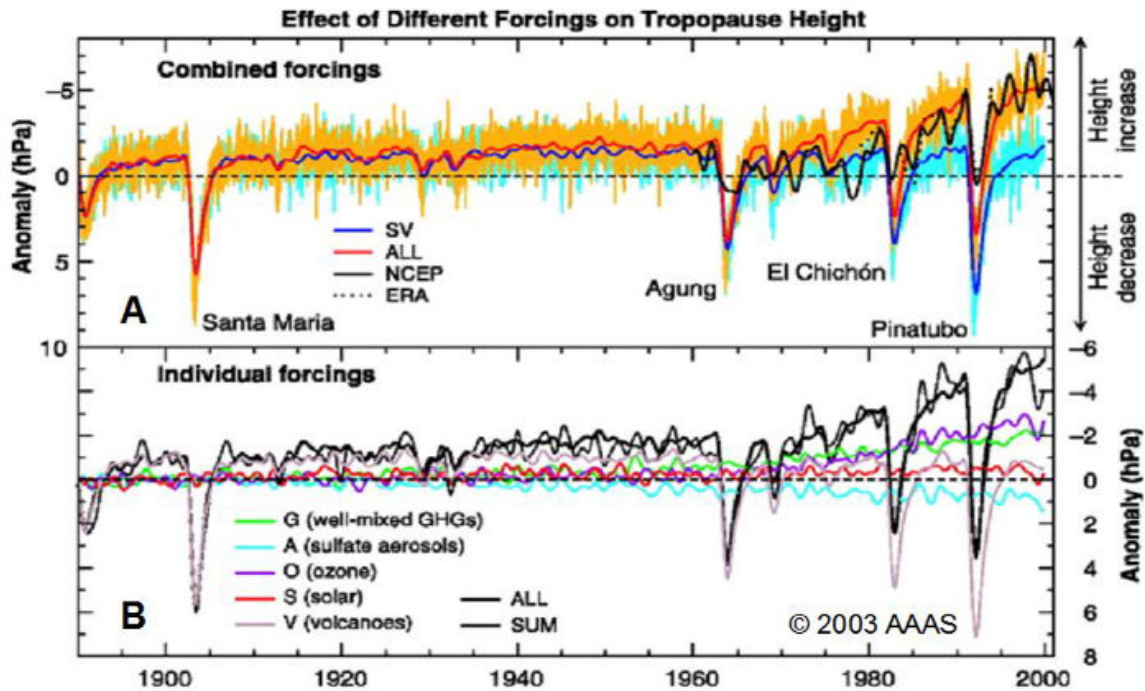


Figure Pew 7: Global average change in tropopause height (From Santer *et al.* 2003; Reprinted with permission from AAAS). (A) Observations (NCEP and ERA) and model results driven by combined solar and volcanic forcing (SV) or combined natural and human-induced forcings (ALL). (B) Change in global average tropopause height according to model results driven by individual forcings as compared to combined forcings (ALL and SUM). “ALL” refers to a single model realization with all forcings included. “SUM” refers to the sum of separate model realizations for individual forcings. Good agreement between ALL and SUM indicates that the influences of the different forcings are additive.

SPPI: The Pew Center is careful not to discuss or evaluate any counter-evidence in its discussion of climatic change at the tropopause. Santer *et al.* (2003), the paper from which the Pew Center took Fig. Pew 7, was criticized by Pielke and Chase (2004) without even challenging (as SPPI has done in this commentary) the ability of climate models –

“[T]he elevation of the globally averaged tropopause reported in [Santer *et al.* 2003] cannot be attributed to any detectable tropospheric warming over this time period [1979-1999]. ... As shown in [Pielke *et al.* 2001], there was no reduction in the equator-to-pole temperature gradient over the 1979-1997 in either hemisphere, contrary to the indication in [Santer *et al.* 2003]. Finally, the climate system is much more complex than defined by tropospheric temperature and tropopause changes. Linear trend analysis is of limited significance ... Changes in global heat storage provide a more appropriate metric to monitor global warming than temperature alone.”

The radiative forcings used in the curve-fitting exercises in Santer *et al.* (2003) are so grievously incomplete as to constitute mere cherry-pickings. Missing forcings include physical effects from land-use changes, both first and second indirect effects from aerosol forcings, transport of water vapor between troposphere and stratosphere, and solar ultraviolet (UV) radiation.

The neglect of the solar UV radiation in a study that was supposed to assess physical and chemical changes in the stratosphere and troposphere is especially unrealistic. The neglect of the effects of observed increases in stratospheric water vapor is also a serious failing in the modeled result. In that regard, the research findings of Forster and Shine (2002) are worth quoting –

“It is now apparent that observed increases in stratospheric water vapor may have contributed significantly to both stratospheric cooling and tropospheric warming over the last few decades. ... [W]e show that if recent estimates for the observed water vapor trends are valid globally they could have contributed a radiative forcing of up to 0.29 W/m² and a lower stratospheric cooling of more than 0.8 K over the last 20 years with these values more than doubling if, as has been suggested, the trend has persisted for the last 40 years. ... [W]ater vapor changes would have been the dominant cause of lower stratospheric temperature trends. In some regions there are indications that the observed trends could be significantly in excess of those that can be explained from [anthropogenic] greenhouse gases and ozone alone.”



Summary

Scientific understanding of the causes of climate change has progressed dramatically in the past few years. Natural internal variability is an inherent feature of the climate system, but it cannot account for the net gain of energy that has been detected within the climate system as a whole. Based on physical principles, the modern increase in the heat content of the global ocean demonstrates that positive external forcing of the climate is underway. Changes in natural external forcings cannot explain the observed global warming of recent decades.

Records of observed climate change at the earth’s surface, in the global ocean, and in the atmosphere, bear the fingerprint of the enhanced greenhouse effect, which is caused by human activities associated with fossil fuel burning and land use. Recent progress in understanding this scientific framework led the 2007 assessment report of the IPCC to conclude –

“Most of the observed increase in globally averaged temperatures since the mid-20th century is very likely [i.e. greater than 90% certainty] due to the observed increase in anthropogenic greenhouse gas concentrations. This is an advance since the [2001 IPCC report] conclusion that ‘most of the observed warming over the last 50 years is likely to have been due to the increase in greenhouse gas concentrations’. Discernible human influences now extend to other aspects of climate, including ocean warming, continental-average temperatures, temperature extremes and wind patterns.”

SPPI: The weight of scientific evidence and of the latest scientific understandings, particularly those raised and discussed in this commentary, points clearly towards the IPCC’s inability or unwillingness to provide reliable and unbiased summaries of the state of scientific research into the changing climate. The IPCC’s process is a misuse of science for increasingly overt political ends.

Fact and objective truth in science matter.

As an antidote to the Pew Center’s attempt to mislead readers into believing that climate science is simple, settled, and complete, SPPI recommends the following summary³ of unedited survey material on “serious inadequacies now that concern climate change research”, which Henderson and Sellers (2008) cite from WMO Report no. 58 (2008) –

- “The rush to emphasize regional climate does not have a scientifically sound basis. Prioritize the models so that weaker ones do not confuse/dilute the signals.
- “Until and unless major oscillations in the Earth System (El Nino-Southern Oscillation (ENSO), Pacific Decadal Oscillation (PDO), North Atlantic Oscillation (NAO) and Atlantic Multidecadal Oscillation (AMO) etc.) can be predicted to the extent that they are predictable, regional climate is not a well defined problem. It may never be. If that is the case then we should say so. It is not just the forecast but the confidence and uncertainty that are just as much a key.

³ http://scienceandpublicpolicy.org/reprint/sellers_ipcc_report.html

- “Climate models need to be exercised for weather prediction; there are necessary but not sufficient things that can best be tested in this framework, which is just beginning to be exploited.
- “The energy budget is really worrisome; we should have had 20 years of ERBE [Earth Radiation Budget Experiment] type data by now – this would have told us about cloud feedback and climate sensitivity. I'm worried that we'll never have a reliable long-term measurement. This combined with accurate ocean heat uptake data would really help constrain the big-picture climate change outcome, and then we can work on the details.
- “[Analyse] the response of models to a single transient 20th century forcing construction. The factors leading to the spread in the responses of models over the 20th century can then be better ascertained, with forcing separated out thus from the mix of the uncertainty factors. The Fourth Assessment Report missed doing this owing essentially to the timelines that were arranged. Adding complexity to models, when some basic elements are not working right (e.g. the hydrological cycle) is not sound science. A hierarchy of models can help in this regard.”

The Pew Center has been too eager and uncritical in its promotion of the IPCC (2007). In *The IPCC report: what the lead authors really think*, published by Henderson-Sellers (2008), an IPCC lead author said, bluntly –

“The Fourth Assessment Report is rather weak at including the latest research and thereby is losing credibility in the science community. During the whole process it loses actuality.”

The same goes for the Pew Center’s “‘Science’ Brief”, which appears partisan rather than impartial, partial rather than complete, political rather than scientific.



Pew References

Barnett, T. P., D. W. Pierce, K. M. AchutaRao, P. J. Gleckler, B. D. Santer, J. M. Gregory, and W. M. Washington. 2005. Penetration of human-induced warming into the world's oceans. *Science* 309:284-287.

Brohan, P., J. J. Kennedy, I. Haris, S. F. B. Tett, and P. D. Jones. 2006. Uncertainty estimates in regional and global observed temperature changes: a new dataset from 1850. *Journal of Geophysical Research* 111:D12106, doi:10.1029/2003JA009974.

Christy, J. R., and R. W. Spencer. 2005. Correcting Temperature Data Sets. *Science* 310:972.

Foukal, P., G. North, and T. Wigley. 2004. A Stellar View on Solar Variations and Climate. *Science* 306:68-69.

HadCRUT3. 2006. HadCRUT3 dataset [Accessed August 29 2006]. Available from <http://hadobs.metoffice.com/hadcrut3/index.html>. Hadley Centre, United Kingdom, 2006.

Annual land air and sea surface temperature anomalies [Accessed Feb. 15 2006] at http://www.met-office.gov.uk/research/hadleycentre/CR_data/Annual/land+sst_web.txt.

Hansen, J., L. Nazarenko, R. Ruedy, M. Sato, J. Willis, A. Del Genio, D. Koch, A. Lacis, K. Lo, S. Menon, T. Novakov, J. Perlwitz, G. Russell, G. A. Schmidt, and N. Tausnev. 2005. Earth's energy imbalance: Confirmation and implications. *Science* 308:1431-1435.

Hansen, J., M. Sato, R. Ruedy, L. Nazarenko, A. Lacis, and 40 others. 2005. Efficacy of climate forcings. *Journal of Geophysical Research-Atmospheres* 110:D18104, doi:10.1029/2005JD005776.

IPCC. 2007. Climate Change 2007: The Physical Science Basis. Summary for Policymakers for Working Group I of the Intergovernmental Panel on Climate Change (Available from www.ipcc.ch).

Levitus, S., J. Antonov, and T. Boyer. 2005. Warming of the world ocean, 1955-2003. *Geophysical Research Letters* 32:L02604, doi:10.1029/2004GL021592.

Mears, C. A., and F. J. Wentz. 2005. The effect of diurnal correction on satellite-derived lower tropospheric temperature. *Science* 310:1548-1551.

Meehl, G. A., W. M. Washington, C. M. Ammann, J. M. Arblaster, T. M. L. Wigley, and C. Tebaldi. 2004. Combinations of natural and anthropogenic forcings in twentieth-century climate. *Journal of Climate* 17:3721-3727.

Mitchell, J. F. B., K. J. Karoly, G.C. Hegerl, F. W. Zwiers, M. R. Allen, J. Marengo, and 28 others. 2001. Detection of climate change and attribution of causes. In *Climate Change 2001: The Scientific Basis. Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change*, edited by J. T. Houghton. New York: Cambridge University Press.

Nagashima, T., H. Shiogama, T. Yokohata, T. Takemura, S. A. Crooks, and T. Nozawa. 2006. Effect of carbonaceous aerosols on surface temperature in the mid twentieth century. *Geophysical Research Letters* 33:L04702, doi:10.1029/2005GL024887.

Santer, B. D., M. F. Wehner, T. M. L. Wigley, R. Sausen, G. A. Meehl, K. E. Taylor, C. Ammann, J. Arblaster, W. M. Washington, J. S. Boyle, and W. Bruggemann. 2003. Contributions of anthropogenic and natural forcing to recent tropopause height changes. *Science* 301:479-483.

Santer, B. D., T. M. L. Wigley, A. J. Simmons, P. W. Kallberg, G. A. Kelly, S. M. Uppala, C. Ammann, J. S. Boyle, W. Bruggemann, C. Doutriaux, M. Fiorino, C. Mears, G. A. Meehl, R. Sausen, K. E. Taylor, W. M. Washington, M. F. Wehner, and F. J. Wentz. 2004. Identification of anthropogenic climate change using a second-generation reanalysis. *Journal of Geophysical Research (Atmospheres)* 109: D21104, doi:10.1029/2004JD005075.

Stott, P. A., S. F. B. Tett, G. S. Jones, M. R. Allen, J. F. B. Mitchell, and G. J. Jenkins. 2000. External control of 20th century temperature by natural and anthropogenic forcings. *Science* 290:2133-2137.

Takemura, T., Y. Tsushima, T. Yokohata, T. Nozawa, T. Nagashima, and T. Nakajima. 2006. Time evolutions of various radiative forcings for the past 150 years estimated by a general circulation model. *Geophysical Research Letters* 33:L19705, doi:10.1029/2006GL026666.



SPPI References

An, S.-I., Kug, J.-S., Ham, Y.-G., and Kang, I.-S. (2008) Successive modulation of ENSO to future greenhouse warming. *Journal of Climate*, vol. 21, 3-21.

Barnett, T. P., Pierce, D.W., AchutaRao, K.M., Gleckler, P.J., Santer, B.D., Gregory, J.M., and Washington, W.M. (2005) Penetration of human-induced warming into the world's oceans. *Science*, vol. 309, 284-287.

Compo, G.P., and Sardeshmukh, P.D. (2008) Oceanic influence on recent continental warming. *Climate Dynamics*, doi:10.1007/s00382-008-0448-9, in press.

Compo, G.P., and Sardeshmukh, P.D. (2008b) Removing ENSO-related variations from the climate record. *Journal of Climate*, submitted (manuscript dated July 19, 2008).

de Laat, A.T.J., and Maurellis, A.N. (2006) Evidence for influence of anthropogenic surface processes on lower tropospheric and surface temperature trends. *International Journal of Climatology*, vol. 26, 897-913.

Forster, P.M.deF., and Shine, K.P. (2002) Assessing the climate impact of trends in stratospheric water vapor. *Geophysical Research Letters*, vol. 29, doi:10.1029/2001GL013909.

Gouretski, V., and Koltermann, K.P. (2007) How much is the ocean really warming? *Geophysical Research Letters*, vol. 34, doi:10.1029/2006GL027834.

Graversen, R.G., Mauritsen, T., Tjernstrom, M., Kallen, E., and Svensson, G. (2008) Vertical structure of recent Arctic warming. *Nature*, vol. 541, 53-56.

Hansen, J., Nazarenko, L., Ruedy, R., Sato, M., Willis, J., Del Genio, A., Koch, D., Lacis, A., Lo, K., Menon, M., Novakov, T., Perlwitz, J., Russell, G., Schmidt, G.A., and Tausnev, N. (2005) Earth's energy imbalance: Confirmation and implications. *Science*, vol. 308, 1431-1435.

Hansen, J., Russell, J., Lacis, A., Fung, I., Rind, D., and Stone, P. (1985) Climate response times: Dependence on climate sensitivity and ocean mixing. *Science*, vol. 229, 857-859.

Henserson-Sellers, A. (2008) The IPCC report: What the lead authors really think. Available at <http://environmentalresearchweb.org/cws/article/opinion/35820>

Knutti, R. (2008) Why are climate models reproducing the observed global surface warming so well? *Geophysical Research Letters*, vol. 35, doi:10.1029/2007GL034932.

Kodera, K., Hori, M.E., Yukimoto, S., and Sigmond, M. (2008) Solar modulation of the Northern Hemisphere winter trends and its implications with increasing CO₂. *Geophysical Research Letters*, vol. 35, doi:10.1029/2007GL031958.

Kucharski, F., and 21 co-authors (2008) The CLIVAR C20C project: Skill of simulating Indian monsoon rainfall on interannual to decadal timescales. Does GHG forcing play a role? *Climate Dynamics*, doi:10.1007/s00382-008-0462-y, in press.

Levitus, S., Antonov, J., and Boyer, T. (2005) Warming of the world ocean, 1955-2003. *Geophysical Research Letters*, vol. 32, doi:10.1029/2004GL021592.

McKittrick, R.R., and Michaels, P.J. (2007) Quantifying the influence of anthropogenic surface processes and inhomogeneities on gridded global climate data. *Journal of Geophysical Research*, vol. 112, doi:10.1029/2007JD008465.

Merryfield, W.J. (2006) Changes to ENSO under CO₂ doubling in a multimodel ensemble. *Journal of Climate*, vol. 19, 4009-4027.

Pielke Sr., R.A., and Chase, T.N. (2004) Comment on "Contributions of anthropogenic and natural forcing to recent tropopause height changes". *Science*, vol. 303, 1771b.

Wild, M. (2008) Short-wave and long-wave surface radiation budgets in GCMs: A review based on the IPCC-AR4/CMIP3 models. *Tellus*, vol. 60A, 932-945.

Willis, J. K., Lyman, J. M., Johnson, G. C., and Gilson, J. (2008) In Situ Data Biases and Recent Ocean Heat Content Variability. *J. Atmos. Oceanic. Technol.*, in press (available online September 11, 2008).

WMO (2008) Future Climate Change Research and Observations: GCOS, WCRP and IGBP Learning from the IPCC Fourth Assessment Report. Report No. 58 available at <http://www.igbp.net/page.php?pid=222>.



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