Climate Sensitivity Reconsidered

The following article has not undergone any scientific peer review, since that is not normal procedure for American Physical Society newsletters. The American Physical Society reaffirms the following position on climate change, adopted by its governing body, the APS Council, on November 18, 2007: "Emissions of greenhouse gases from human activities are changing the atmosphere in ways that affect the Earth's climate."

By Christopher Monckton of Brenchley

Abstract

The Intergovernmental Panel on Climate Change (IPCC, 2007) concluded that anthropogenic CO_2 emissions probably caused more than half of the “global warming” of the past 50 years and would cause further rapid warming. However, global mean surface temperature has not risen since 1998 and may have fallen since late 2001. The present analysis suggests that the failure of the IPCC’s models to predict this and many other climatic phenomena arises from defects in its evaluation of the three factors whose product is climate sensitivity:

1. Radiative forcing ΔF;
2. The no-feedbacks climate sensitivity parameter κ; and
3. The feedback multiplier f.

Some reasons why the IPCC’s estimates may be excessive and unsafe are explained. More importantly, the conclusion is that, perhaps, there is no “climate crisis”, and that currently-fashionable efforts by governments to reduce anthropogenic CO_2 emissions are pointless, may be ill-conceived, and could even be harmful.

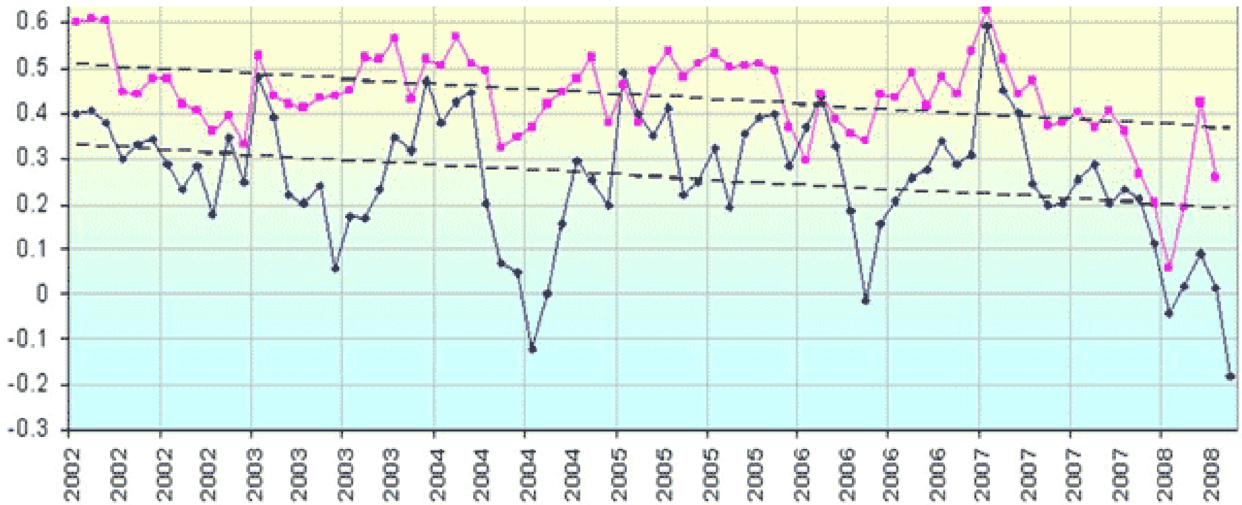
The context

LOBALLY-AVERAGED land and sea surface absolute temperature T_S has not risen since 1998 (Hadley Center; US National Climatic Data Center; University of Alabama at Huntsville; etc.). For almost seven years, T_S may even have fallen (Figure 1). There may be no new peak until 2015 (Keenlyside*et al.*, 2008).

The models heavily relied upon by the Intergovernmental Panel on Climate Change (IPCC) had not projected this multidecadal stasis in “global warming”; nor (until trained *ex post facto*) the fall in T_S from 1940-1975; nor 50 years’ cooling in Antarctica (Doran *et al.,* 2002) and the Arctic (Soon, 2005); nor the absence of ocean warming since 2003 (Lyman *et al.,* 2006; Gouretski&Koltermann, 2007); nor the onset, duration, or intensity of the Madden-Julian intraseasonal oscillation, the Quasi-Biennial Oscillation in the tropical stratosphere, El Nino/La Nina oscillations, the Atlantic Multidecadal Oscillation, or the Pacific Decadal Oscillation that has recently transited from its warming to its cooling phase (oceanic oscillations which, on their own, may account for all of the observed warmings and coolings over the past half-century: Tsonis*et al.,* 2007); nor the magnitude nor duration of multi-century events such as the Mediaeval Warm Period or the Little Ice Age; nor the cessation since 2000 of the previously-observed growth in atmospheric methane concentration (IPCC, 2007); nor the active 2004 hurricane season; nor the inactive subsequent seasons; nor the UK flooding of 2007 (the Met Office had forecast a summer of prolonged droughts only six weeks previously); nor the solar Grand Maximum of the past 70 years, during which the Sun was more active, for longer, than at almost any similar period in the past 11,400 years (Hathaway, 2004; Solanki*et al.*, 2005); nor the consequent surface “global warming” on Mars, Jupiter, Neptune’s largest moon, and even distant Pluto; nor the eerily- continuing 2006 solar minimum; nor the consequent, precipitate decline of ~0.8 °C in T_S from January 2007 to May 2008 that has canceled out almost all of the observed warming of the 20th century.

Figure 1

Mean global surface temperature anomalies (°C), 2001-2008

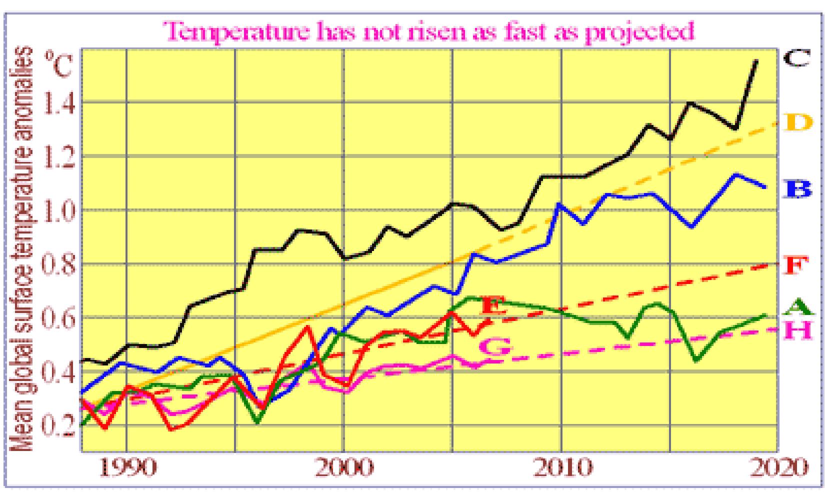


Since the phase-transition in mean global surface temperature late in 2001, a pronounced downtrend has set in. In the cold winter of 2007/8, record sea-ice extents were observed at both Poles. The January-to-January fall in temperature from 2007-2008 was the greatest since global records began in 1880. Data sources: Hadley Center monthly combined land and sea surface temperature anomalies; University of Alabama at Huntsville Microwave Sounding Unit monthly lower-troposphere anomalies; Linear regressions – – – – – – –

An early projection of the trend in T_S in response to "global warming" was that of Hansen (1988), amplifying Hansen (1984) on quantification of climate sensitivity. In 1988, Hansen showed Congress a graph projecting rapid increases in T_S to 2020 through "global warming" (Fig. 2):

Figure 2

Global temperature projections and outturns, 1988-2020



*Hansen (1988) projected that global temperature would stabilize **(A)** if global carbon dioxide concentration were controlled from 1988 and static from 2000: otherwise temperature would rise rapidly **(B-C).** IPCC (1990) agreed **(D).** However, these projections proved well above the National Climate Data Center's outturn **(E-F),** which, in contrast to the Hadley Center and UAH records (Fig. 1), show a modest rise in temperature from 1998-2007. If McKitrick (2007) **(G,H)** is correct that temperature since 1980 has risen at only half of the observed rate, outturn tracks Hansen's CO_2 stabilization case **(A)**, although emissions have risen rapidly since 1988.*

To what extent, then, has humankind warmed the world, and how much warmer will the world become if the current rate of increase in anthropogenic CO_2 emissions continues? Estimating "climate sensitivity" – the magnitude of the change in T_S after doubling CO_2 concentration from the pre-industrial 278 parts per million to ~550 ppm – is the central question in the scientific debate about the climate. The official answer is given in IPCC (2007):

"It is *very likely* that anthropogenic greenhouse gas increases caused most of the observed increase in [T_S] since the mid-20th century. … The equilibrium global average warming expected if carbon dioxide concentrations were to be sustained at 550 ppm is *likely* to be in the range 2-4.5 °C above pre-industrial values, with a best estimate of about 3 ° C."

Here as elsewhere the IPCC assigns a 90% confidence interval to "*very likely",* rather than the customary 95% (two standard deviations). There is no good statistical basis for any such quantification, for the object to which it is applied is, in the formal sense, chaotic. The climate is "a complex, non-linear, chaotic object" that defies long-run prediction of its future states (IPCC, 2001), unless the initial state of its millions of variables is known to a precision that is in practice unattainable, as Lorenz (1963; and see Giorgi, 2005) concluded in the celebrated paper that founded chaos theory –

"Prediction of the sufficiently distant future is impossible by any method, unless the present conditions are known exactly. In view of the inevitable inaccuracy and incompleteness of weather observations, precise, very-long-range weather forecasting would seem to be non-existent.".

The *Summary for Policymakers* in IPCC (2007) says –

"The CO_2radiative forcing increased by 20% in the last 10 years (1995-2005)."

Natural or anthropogenic CO_2 in the atmosphere induces a "radiative forcing" ΔF, defined by IPCC (2001: ch.6.1) asa change in net (down minus up) radiant-energy flux at the tropopause in response to a perturbation. Aggregate forcing is natural (pre-1750) plus anthropogenic-era (post-1750) forcing. At 1990, aggregate forcing from CO_2 concentration was ~27 W m^{-2} (Kiehl&Trenberth, 1997). From 1995-2005, CO_2 concentration rose 5%, from 360 to 378 W m^{-2}, with a consequent increase in aggregate forcing (from Eqn. 3 below) of ~0.26 W m^{-2}, or <1%. That is one-twentieth of the value stated by the IPCC. The absence of any definition of "radiative forcing" in the 2007 *Summary* led many to believe that the aggregate (as opposed to anthropogenic) effect of CO_2 on T_S had increased by 20% in 10 years. The IPCC – despite requests for correction – retained this confusing statement in its report.

Such solecisms throughout the IPCC's assessment reports (including the insertion, after the scientists had completed their final draft, of a table in which four decimal points had been right-shifted so as to multiply tenfold the observed contribution of ice-sheets and glaciers to sea-level rise), combined with a heavy reliance upon computer models unskilled even in short-term projection, with initial values of key variables unmeasurable and unknown, with advancement of multiple, untestable, non-Popper-falsifiable theories, with a quantitative assignment of unduly high statistical confidence levels to non-quantitative statements that are ineluctably subject to very large uncertainties, and, above all, with the now-prolonged failure of T_S to rise as predicted (Figures 1, 2), raise questions about the reliability and hence policy-relevance of the IPCC's central projections.

Dr. RajendraPachauri, chairman of the UN Intergovernmental Panel on Climate Change (IPCC), has recently said that the IPCC's evaluation of climate sensitivity must now be revisited. This paper is a respectful contribution to that re-examination.

The IPCC's method of evaluating climate sensitivity

We begin with an outline of the IPCC's method of evaluating climate sensitivity. For clarity we will concentrate on central estimates. The IPCC defines climate sensitivity as equilibrium temperature change ΔT_λin response to all anthropogenic-era radiativeforcings and consequent "temperature feedbacks" – further changes in T_S that occur because T_S has already changed in response to a forcing – arising in response to the doubling of pre-industrial CO_2 concentration (expected later this century). ΔT_λ is, at its simplest, the product of three factors: the sum ΔF_{2x} of all anthropogenic-era radiativeforcingsat CO_2 doubling; the base or "no-feedbacks" climate sensitivity parameter κ; and the feedback multiplier f, such that the final or "with-feedbacks" climate sensitivity parameter $\lambda = \kappa f$. Thus –

$\Delta T_\lambda = \Delta F_{2x}\, \kappa\, f = \Delta F_{2x}\lambda$, (1)

where $f = (1 - b\kappa)^{-1}$, (2)

such that b is the sum of all climate-relevant temperature feedbacks. The definition of f in Eqn. (2) will be explained later. We now describe *seriatim* each of the three factors in ΔT_λ: namely, ΔF_{2x}, κ, and f.

1. Radiative forcing $\Delta F CO_2$,where (C/C_0) is a proportionate increase in CO_2 concentration, is given by several formulae in IPCC (2001, 2007). The simplest, following Myrhe (1998), is Eqn. (3) –

$\Delta F CO_2 \approx 5.35 \ln(C/C_0) ==> \Delta F 2x CO_2 \approx 5.35 \ln 2 \approx 3.708$ W m^{-2}. (3)

To $\Delta F2xCO_2$ is added the slightly net-negative sum of all other anthropogenic-era radiativeforcings, calculated from IPCC values (Table 1), to obtain total anthropogenic-era radiative forcing ΔF_{2x} at CO_2 doubling (Eqn. 3). Note that forcings occurring in the anthropogenic era may not be anthropogenic.

Table 1

Evaluation of ΔF_{2x} from the IPCC's anthropogenic-era forcings

Forcing agent(yellow: values from IPCC, 2007)	*1750-2005*	*1750-2xCO$_2$*	*Method*
CO_2 anthropogenic-era radiative forcing $\Delta F2xCO_2$	1.66 W m^{-2}	3.71 W m^{-2}	From Eqn. (3)
LLGHGs: CH_4 0.48; $NO_2$0.16; Halocarbons 0.34	0.98W m^{-2}		
SLGHGs: $O_3$0.30; CH_4 water vapor0.07	0.37 W m^{-2}		
All GHGs' anthropogenic-era forcings	3.01W m^{-2}	4.95 W m^{-2}	3.71 / 75%
Contrails 0.01; Surfc.albedo–0.10; Aerosol –1.20	–1.29 W m^{-2}	–1.29 W m^{-2}	Held constant
Total anthropogenic-era forcings ΔF_{2x} …	1.72 W m^{-2}	3.66 W m^{-2}	
… adjusted for IPCC probability-density function:	1.60 W m^{-2}	3.41 W m^{-2}	3.35 x 1.60 / 1.72

Anthropogenic-era radiativeforcings from CO_2, from long-lived (LLGHG) and short-lived (SLGHG) greenhouse gases are added to other forcings to yield total anthropogenic-era forcings ΔF_{2x}, which are then reduced by a probability-density function. The column for 1750-2005 summarizes the values given in IPCC (2007). The column for forcings from 1750 to CO_2 doubling proceeds differently, since IPCC (2007) does not publish projected values for individual forcings at CO_2 doubling other than that for CO_2 itself. However, IPCC (2001) projected that CO_2forcings by 2050-2100, when CO_2 doubling is expected, would represent 70-80% of all greenhouse-gas forcings. That projection is followed here, while non-greenhouse-gas forcings (which are strongly net-negative) are conservatively held constant. To preserve the focus on anthropogenic forcings, the IPCC's minuscule estimate of the solar forcing during the anthropogenic era is omitted.

From the anthropogenic-era forcings summarized in Table 1, we obtain the first of the three factors –

$\Delta F2x \approx 3.405$ W m^{-2}. (4)

2. The base or "no-feedbacks" climate sensitivity parameter *κ*, where ΔT_κ is the response of T_S to radiativeforcings ignoring temperature feedbacks, ΔT_λ is the response of T_S to feedbacks as well as forcings, and b is the sum in W m^{-2} °K^{-1}of all individual temperature feedbacks, is –

$\kappa = \Delta T_\kappa / \Delta F2x$ °K W^{-1} m^2, by definition; (5)

$= \Delta T_\lambda / (\Delta F2x + b\Delta T_\lambda)$ °K W^{-1} m^2. (6)

In Eqn. (5), ΔT_κ, estimated by Hansen (1984) and IPCC (2007) as 1.2-1.3 °K at CO_2 doubling, is the change in *surface* temperature in response to a *tropopausal*forcing ΔF_{2x}, ignoring any feedbacks.

ΔT_κ is not directly measurable in the atmosphere because feedbacks as well as forcings are present. Instruments cannot distinguish between them. However, from Eqn. (2) we may substitute $1 / (1 – b\kappa)$ for f in Eqn. (1), rearranging terms to yield a useful second identity, Eqn. (6), expressing κ in terms of ΔT_λ, which is measurable, albeit with difficulty and subject to great uncertainty (McKitrick, 2007).

IPCC (2007) does not mention κ and, therefore, provides neither error-bars nor a "Level of Scientific Understanding" (the IPCC's subjective measure of the extent to which enough is known about a variable to render it useful in quantifying climate sensitivity). However, its implicit value $\kappa \approx 0.313$ °K W^{-1} m^2, shown in Eqn. 7, may be derived using Eqns. 9-10 below, showing it to be the reciprocal of the estimated "uniform-temperature" radiative cooling response –

"Under these simplifying assumptions the amplification [*f*] of the global warming from a feedback parameter [*b*] (in W m^{-2} °C^{-1}) with no other feedbacks operating is 1 / (1 – [$b\kappa^{-1}$]), where [$-\kappa^{-1}$] is the 'uniform temperature' radiative cooling response (of value approximately –3.2 W m^{-2} °C^{-1}; Bony *et al.*, 2006). If *n* independent feedbacks operate, [*b*] is replaced by ($\lambda_1 + \lambda_2 + \ldots \lambda_n$)." (IPCC, 2007: ch.8, footnote).

Thus, $\kappa \approx 3.2^{-1} \approx 0.313$°K W^{-1} m^2. (7)

3. The feedback multiplier *f* is a unitless variable by which the base forcing is multiplied to take account of mutually-amplified temperature feedbacks. A "temperature feedback" is a change in T_S that occurs precisely because T_S has already changed in response to a forcing or combination of forcings. An instance: as the atmosphere warms in response to a forcing, the carrying capacity of the space occupied by the atmosphere for water vapor increases near-exponentially in accordance with the Clausius-Clapeyron relation. Since water vapor is the most important greenhouse gas, the growth in its concentration caused by atmospheric warming exerts an additional forcing, causing temperature to rise further. This is the "water-vapor feedback". Some 20 temperature feedbacks have been described, though none can be directly measured. Most have little impact on temperature. The value of each feedback, the interactions between feedbacks and forcings, and the interactions between feedbacks and other feedbacks, are subject to very large uncertainties.

Each feedback, having been triggered by a change in atmospheric temperature, itself causes a temperature change. Consequently, temperature feedbacks amplify one another. IPCC (2007: ch.8) defines *f* in terms of a form of the feedback-amplification function for electronic circuits given in Bode (1945), where *b* is the sum of all individual feedbacks before they are mutually amplified:

$f = (1 - b\kappa)^{-1}$ (8)

$= \Delta T_\lambda / \Delta T_\kappa$

Note the dependence of *f* not only upon the feedback-sum *b* but also upon κ –

$\Delta T_\lambda = (\Delta F + b\Delta T_\lambda)\kappa$

$\Longrightarrow \Delta T_\lambda (1 - b\kappa) = \Delta F\kappa$

$\Longrightarrow \Delta T_\lambda = \Delta F\kappa(1 - b\kappa)^{-1}$

$\Longrightarrow \Delta T_\lambda / \Delta F = \lambda = \kappa(1 - b\kappa)^{-1} = \kappa f$

$\Longrightarrow f = (1 - b\kappa)^{-1} \approx (1 - b/3.2)^{-1}$

$\Longrightarrow \kappa \approx 3.2^{-1} \approx 0.313$ °K W^{-1} m^2. (9)

Equivalently, expressing the feedback loop as the sum of an infinite series,

$\Delta T_\lambda = \Delta F\kappa + \Delta F\kappa^2 b + \Delta F\kappa^2 b^2 + \ldots$

$= \Delta F\kappa(1 + \kappa b + \kappa b^2 + \ldots)$

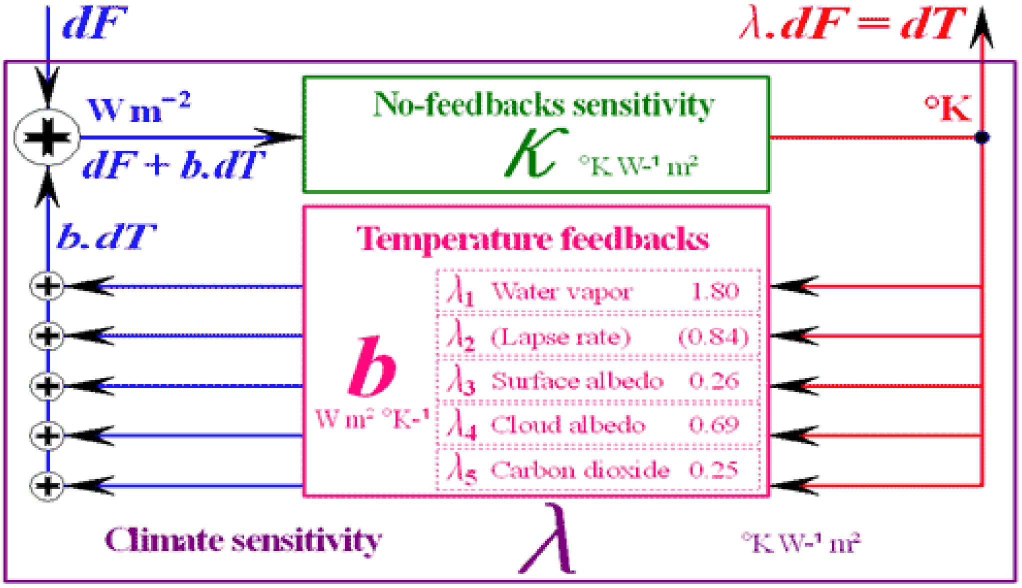
$= \Delta F\kappa(1 - \kappa b)^{-1}$

$= \Delta F\kappa f$

$\Longrightarrow \lambda = \Delta T_\lambda / \Delta F = \kappa f$ (10)

Figure 3

Bode (1945) feedback amplification schematic



A forcing dF is input by multiplication to the final or "with-feedbacks" climate sensitivity parameter λ = κf, yielding the output dT = dFλ = dFκf. To find λ = κf, the base or "no-feedbacks" climate sensitivity parameter κ is successively amplified round the feedback-loop by feedbacks summing to b.

For the first time, IPCC (2007) quantifies the key individual temperature feedbacks summing to *b*:

"In AOGCMs, the water vapor feedback constitutes by far the strongest feedback, with a multi-model mean and standard deviation … of 1.80 ± 0.18 W $m^{-2}K^{-1}$, followed by the negative lapse rate feedback (–0.84 ± 0.26 W m^{-2} K^{-1}) and the surface albedo feedback (0.26 ± 0.08 W m^{-2} K^{-1}). The cloud feedback mean is 0.69 W m^{-2} $K^{-1}$with a very large inter-model spread of ±0.38 W m^{-2} K^{-1}." (Soden& Held, 2006).

To these we add the CO_2 feedback, which IPCC (2007, ch.7) separately expresses not as W m^{-2}°K^{-1} but as concentration increase per CO_2 doubling: [25, 225] ppmv, central estimate *q* = 87 ppmv. Where *p* is concentration at first doubling, the proportionate increase in atmospheric CO_2 concentration from the CO_2 feedback is *o* = (*p* + *q*) / *p* = (556 + 87) / 556 ≈ 1.16. Then theCO_2 feedback is –

λ_{CO2}= zln(*o*) / dT_λ ≈ 5.35 ln(1.16) / 3.2 ≈ 0.25 W m^{-2} K^{-1}. (11)

The CO_2 feedback is added to the previously-itemized feedbacks to complete the feedback-sum*b*:

b = 1.8 – 0.84 + 0.26 + 0.69 + 0.25 ≈ 2.16 W m^{-2} °K^{-1}, (12)

so that, where κ= 0.313, the IPCC's unstated central estimate of the value of the feedback factor *f* is at the lower end of the range *f* = 3-4 suggested in Hansen *et al.* (1984) –

$f = (1 - b\kappa)^{-1} \approx (1 - 2.16 \times 0.313)^{-1} \approx 3.077$. (13)

Final climate sensitivity ΔT_λ,after taking account of temperature feedbacks as well as the forcings that triggered them,is simply the product of the three factors described in Eqn. (1), each of which we have briefly described above. Thus, at CO_2 doubling, –

$\Delta T_\lambda = \Delta F_{2x} \kappa f \approx 3.405 \times 0.313 \times 3.077 \approx 3.28$ °K (14)

IPCC (2007) gives dT_λon [2.0, 4.5] °K at CO_2 doubling, central estimate dT_λ≈ 3.26 °K, demonstrating that the IPCC's method has been faithfully replicated. There is a further checksum, –

$\Delta T_\kappa = \Delta T_\lambda / f = \kappa \Delta F_{2x} = 0.313 \times 3.405 \approx 1.1$ °K, (15)

sufficiently close to the IPCC's estimate ΔT_κ ≈ 1.2 °K, based on Hansen (1984), who had estimated a range 1.2-1.3 °K based on his then estimate that the radiative forcing ΔF_{2xCO2} arising from a CO_2 doubling would amount to 4.8 W m^{-2}, whereas the IPCC's current estimate is ΔF_{2xCO2} = 3.71 W m^{-2} (see Eqn. 2), requiring a commensurate reduction in

ΔT_κ that the IPCC has not made.

A final checksum is provided by Eqn. (5), giving a value identical to that of the IPCC at Eqn (7):

$\kappa = \Delta T_\lambda / (\Delta F_{2x} + b\Delta T_\lambda)$

$\approx 3.28 / (3.405 + 2.16 \times 3.28)$

$\approx 0.313°K\ W^{-1}\ m^2$. (16)

Having outlined the IPCC's methodology, we proceed to re-evaluate each of the three factors in dT_λ. None of these three factors is directly mensurable. For this and other reasons, it is not possible to obtain climate sensitivity numerically using general-circulation models: for, as Akasofu (2008) has pointed out, climate sensitivity must be an *input to* any such model, not an *output from* it.

In attempting a re-evaluation of climate sensitivity, we shall face the large uncertainties inherent in the climate object, whose complexity, non-linearity, and chaoticity present formidable initial-value and boundary-value problems. We cannot measure total radiative forcing, with or without temperature feedbacks, because radiative and non-radiative atmospheric transfer processes combined with seasonal, latitudinal, and altitudinal variabilities defeat all attempts at reliable measurement. We cannot even measure changes in T_S to within a factor of two (McKitrick, 2007).

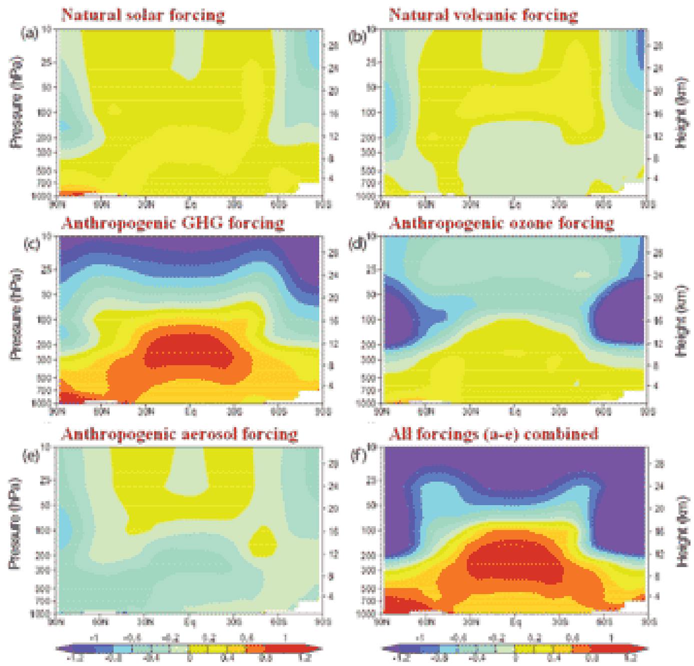
Even satellite-based efforts at assessing total energy-flux imbalance for the whole Earth-troposphere system are uncertain. Worse, not one of the individual forcings or feedbacks whose magnitude is essential to an accurate evaluation of climate sensitivity is mensurable directly, because we cannot distinguish individual forcings or feedbacks one from another in the real atmosphere, we can only guess at the interactions between them, and we cannot even measure the relative contributions of all forcings and of all feedbacks to total radiative forcing. Therefore we shall adopt two approaches: theoretical demonstration (where possible); and empirical comparison of certain outputs from the models with observation to identify any significant inconsistencies.

Radiative forcing ΔF_{2x} reconsidered

We take the second approach with ΔF_{2x}. Since we cannot measure any individual forcing directly in the atmosphere, the models draw upon results of laboratory experiments in passing sunlight through chambers in which atmospheric constituents are artificially varied; such experiments are, however, of limited value when translated into the real atmosphere, where radiative transfers and non-radiative transports (convection and evaporation up, advection along, subsidence and precipitation down), as well as altitudinal and latitudinal asymmetries, greatly complicate the picture. Using these laboratory values, the models attempt to produce latitude-versus-altitude plots to display the characteristic signature of each type of forcing. The signature or fingerprint of anthropogenic greenhouse-gas forcing, as predicted by the models on which the IPCC relies, is distinct from that of any other forcing, in that the models project that the rate of change in temperature in the tropical mid-troposphere – the region some 6-10 km above the surface – will be twice or thrice the rate of change at the surface (Figure 4):

Figure 4

Temperature fingerprints of five forcings

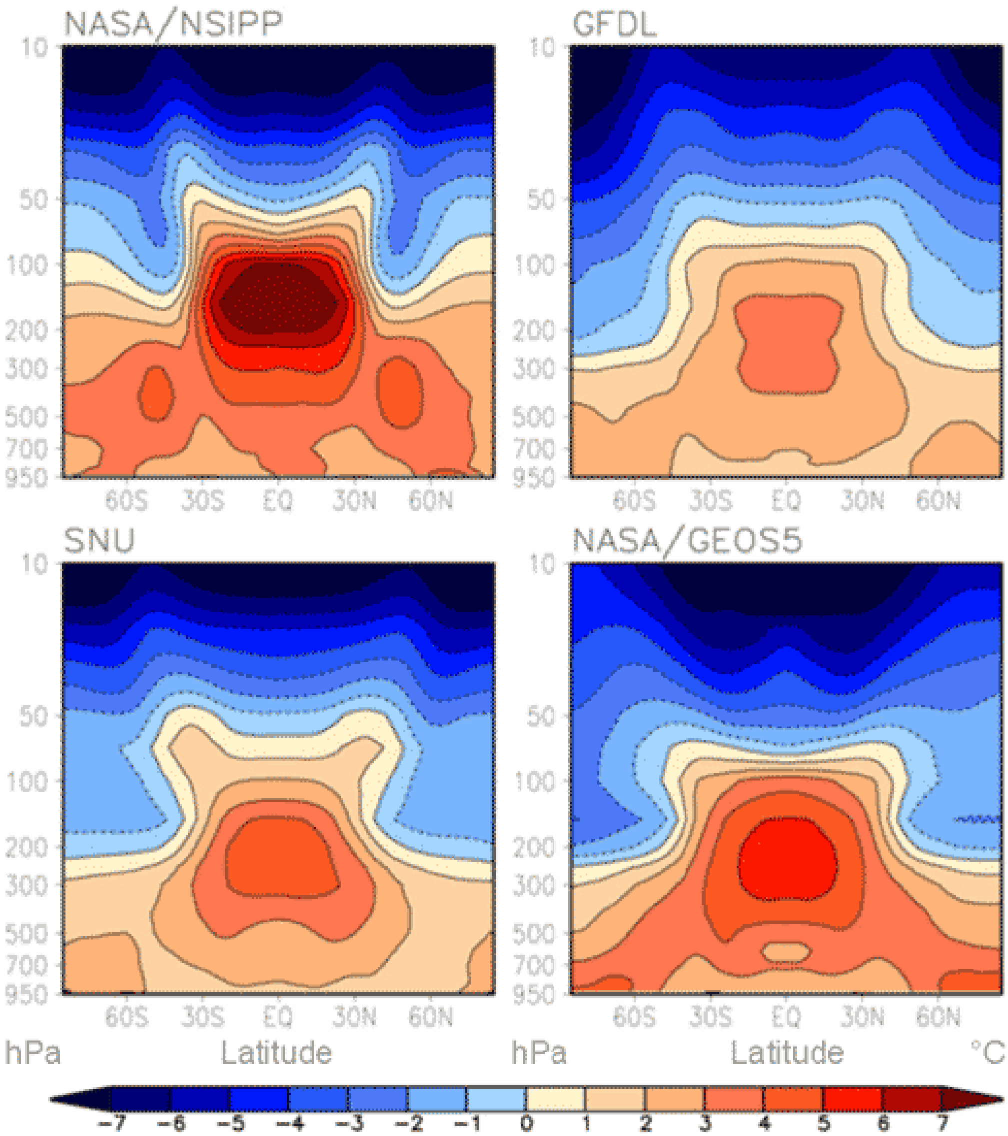


Modeledzonal mean atmospheric temperature change (ºC per century, 1890-1999) in response to five distinct forcings (a-e), and to all five forcings combined (f). Altitude is in hPa (left scale) and km (right scale) vs. latitude (abscissa). ***Source:*** *IPCC (2007).*

The fingerprint of anthropogenic greenhouse-gas forcing is a distinctive “hot-spot” in the tropical mid-troposphere. Figure 4 shows altitude-vs.-latitude plots from four of the IPCC’s models:

Figure 5

Fingerprints of anthropogenic warming projected by four models

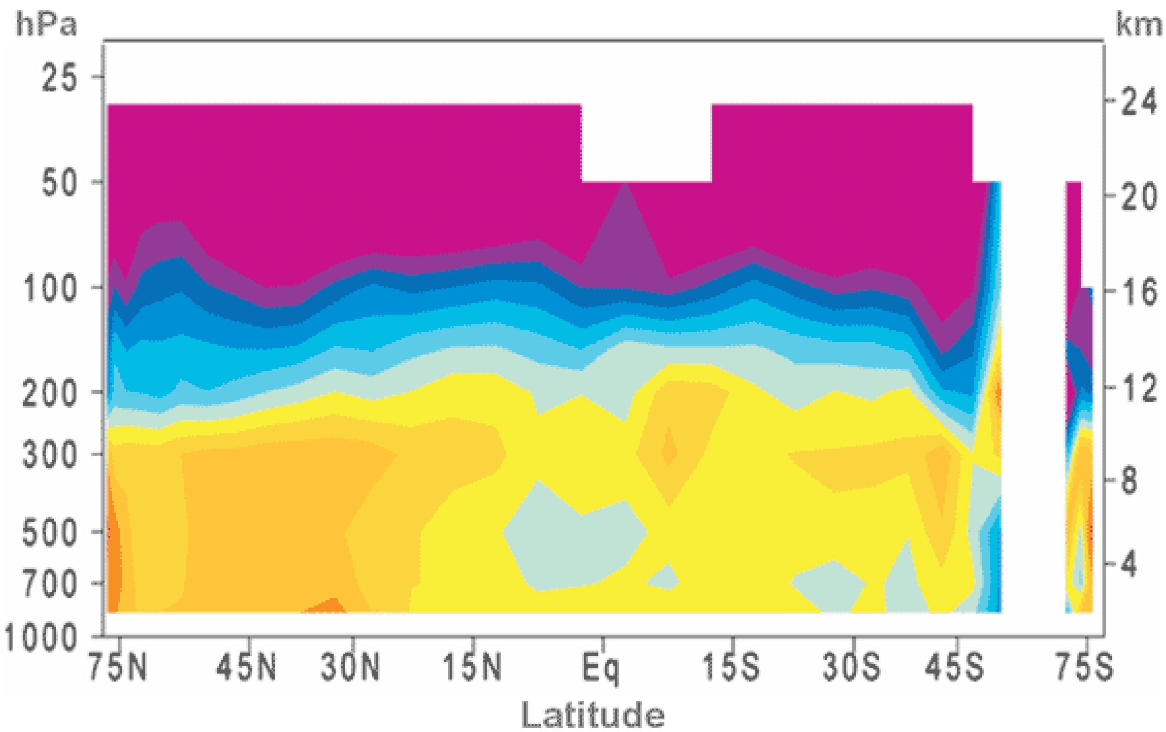


Zonal mean equilibrium temperature change (°C) at CO_2 doubling (2x CO_2 – control), as a function of latitude and pressure (hPa) for 4 general-circulation models. All show the projected fingerprint of anthropogenic greenhouse-gas warming: the tropical mid-troposphere "hot-spot" is projected to warm at twice or even thrice the surface rate. ***Source:*** *Lee et al. (2007).*

However, as Douglass *et al.* (2004) and Douglass *et al.* (2007) have demonstrated, the projected fingerprint of anthropogenic greenhouse-gas warming in the tropical mid-troposphere is not observed in reality. Figure 6 is a plot of observed tropospheric rates of temperature change from the Hadley Center for Forecasting. In the tropical mid-troposphere, at approximately 300 hPa pressure, the model-projected fingerprint of anthropogenic greenhouse warming is absent from this and all other observed records of temperature changes in the satellite and radiosonde eras:

Figure 6

The absent fingerprint of anthropogenic greenhouse warming



Altitude-vs.-latitude plot of observed relative warming rates in the satellite era. The greater rate of warming in the tropical mid-troposphere that is projected by general-circulation models is absent in this and all other observational datasets, whether satellite or radiosonde. Altitude units are hPa (left) and km (right). ***Source:*** *Hadley Centre for Forecasting (HadAT, 2006).*

None of the temperature datasets for the tropical surface and mid-troposphere shows the strong differential warming rate predicted by the IPCC's models. Thorne *et al.* (2007) suggested that the absence of the mid-tropospheric warming might be attributable to uncertainties in the observed record: however, Douglass *et al.* (2007) responded with a detailed statistical analysis demonstrating that the absence of the projected degree of warming is significant in all observational datasets.

Allen *et al.* (2008) used upper-atmosphere wind speeds as a proxy for temperature and concluded that the projected greater rate of warming at altitude in the tropics is occurring in reality. However, satellite records, such as the RSS temperature trends at varying altitudes, agree with the radiosondes that the warming differential is not occurring: they show that not only absolute temperatures but also warming rates decline with altitude.

There are two principal reasons why the models appear to be misrepresenting the tropical atmosphere so starkly. First, the concentration of water vapor in the tropical lower troposphere is already so great that there is little scope for additional greenhouse-gas forcing. Secondly, though the models assume that the concentration of water vapor will increase in the tropical mid-troposphere as the space occupied by the atmosphere warms, advection transports much of the additional water vapor poleward from the tropics at that altitude.

Since the great majority of the incoming solar radiation incident upon the Earth strikes the tropics, any reduction in tropical radiative forcing has a disproportionate effect on mean global forcings. On the basis of Lindzen (2007), the anthropogenic-ear radiative forcing as established in Eqn. (3) are divided by 3 to take account of the observed failure of the tropical mid-troposphere to warm as projected by the models –

$\Delta F_{2x} \approx 3.405 / 3 \approx 1.135$ W m^{-2}. (17)

The "no-feedbacks" climate sensitivity parameter *κ* reconsidered

The base climate sensitivity parameter *κ*is the most influential of the three factors of ΔT_λ: for the final or "with-feedbacks" climate sensitivity parameter *λ* is the product of *κ*and the feedback factor *f*, which is itselfdependent not only on the sum *b* of all climate-relevant temperature feedbacks but also on *κ*.Yet *κ* has received limited attention in the literature. In IPCC (2001, 2007) it is not mentioned. However, its value may be deduced from hints in the IPCC's reports. IPCC (2001, ch. 6.1) says:

"The climate sensitivity parameter (global mean surface temperature response ΔT_S to the radiative forcing ΔF) is defined as $\Delta T_S / \Delta F = \lambda$ {6.1} (Dickinson, 1982; WMO, 1986; Cess*et al*., 1993). Equation {6.1} is defined for the transition of the surface-troposphere system from one equilibrium state to another in response to an externally imposed radiative perturbation. In the one-dimensional radiative-convective models, wherein the concept was first initiated, $\lambda$is a nearly invariant parameter (typically, about 0.5 °K W^{-1} m^2; Ramanathan*et al.*, 1985) for a variety of radiativeforcings, thus introducing the notion of a possible universality of the relationship between forcing and response."

Since $\lambda = \kappa f = \kappa(1 - b\kappa)^{-1}$ (Eqns. 1, 2), where λ = 0.5 °K W^{-1} m^2 and $b \approx$ 2.16 W m^{-2} $°K^{-1}$ (Eqn. 12), it is simple to calculate that, in 2001, one of the IPCC's values for *f* was 2.08. Thus the value *f* = 3.077 in IPCC (2007) represents a near-50% increase in the value of *f* in only five years. Where *f* = 2.08, $\kappa = \lambda / f \approx 0.5 / 2.08 \approx 0.24$ °K W^{-1} m^2, again substantially lower than the value implicit in IPCC (2007). Some theory will, therefore, be needed.

The fundamental equation of radiative transfer at the emitting surface of an astronomical body, relating changes in radiant-energy flux to changes in temperature, is the Stefan-Boltzmann equation –

$F = \varepsilon \sigma T^4$ W m^{-2}, (18)

where*F* is radiant-energy flux at the emitting surface; $\varepsilon$is emissivity, set at 1 for a blackbody that absorbs and emits all irradiance reaching its emitting surface (by Kirchhoff's law of radiative transfer, absorption and emission are equal and simultaneous), 0 for a whitebody that reflects all irradiance, and (0, 1) for a graybody that partly absorbs/emits and partly reflects; and $\sigma \approx 5.67 \times 10^{-8}$ is the Stefan-Boltzmann constant.

Differentiating Eqn. (18) gives –

$\kappa = dT / dF = (dF / dT)^{-1} = (4 \varepsilon \sigma T^3)^{-1}$ °K W^{-1} m^2. (19)

Outgoing radiation from the Earth's surface is chiefly in the near-infrared. Its peak wavelength λ_{max} is determined solely by the temperature of the emitting surface in accordance with Wien's Displacement Law, shown in its simplest form in Eqn. (20):

$\lambda_{max} = 2897 / T_S = 2897 / 288 \approx 10$ µm. (20)

Since the Earth/troposphere system is a blackbody with respect to the infrared radiation that Eqn. (20) shows we are chiefly concerned with, we will not introduce any significant error if ε = 1, giving the blackbody form of Eqn. (19) –

$\kappa = dT / dF = (4\sigma T^3)^{-1}$ °K W^{-1} m^2. (21)

At the Earth's surface, $T_S \approx$ 288 °K, so that $\kappa_S \approx$ 0.185 °K W^{-1} m^2. At the characteristic-emission level, Z_C, the variable altitude at which incoming and outgoing radiative fluxes balance, $T_C \approx$ 254 °K, so that $\kappa_C \approx$ 0.269 °K W^{-1} m^2. The value $\kappa_C \approx$ 0.24, derived from the typical final-sensitivity value λ = 0.5 given in IPCC (2001), falls between the surface and characteristic-emission values for κ.

However, the IPCC, in its evaluation of κ, does not follow the rule that in the Stefan-Boltzmann equation the temperature and radiant-energy flux must be taken at the same level of the atmosphere. The IPCC's value for κ is dependent upon temperature at the surface and radiant-energy flux at the tropopause, so that its implicit value $\kappa \approx$ 0.313 °K W^{-1} m^2 is considerably higher than either κ_S or κ_C.

IPCC (2007) cites Hansen *et al.* (1984), who say –

"Our three-dimensional global climate model yields a warming of ~4 ºC for … doubled CO_2. This indicates a net feedback factor *f*= 3-4, because [the forcing at CO_2 doubling] would cause the earth's surface temperature to warm 1.2-1.3 ºC to restore radiative balance with space, if other factors remained unchanged."

Hansen says dF_{2x} is equivalent to a 2% increase in incoming total solar irradiance (TSI). Top-of-atmosphere TSI $S \approx$ 1368 W m^2, albedoα = 0.31, and Earth's radius is *r*. Then, at the characteristic emission level Z_C,

$F_C = S(1 - \alpha)(\pi r^2 / 4\pi r^2) \approx 1368 \times 0.69 \times (1/4) \approx 236$ W m^{-2}. (22)

Thus a 2% increase in $F_C$is equivalent to 4.72 W m^{-2}, rounded up by Hansen to 4.8 W m^{-2}, implying that $\kappa \approx 1.25 / 4.8 \approx 0.260$ °K W^{-1} m^2. However, Hansen, in his Eqn. {14}, prefers 0.29 W m^{-2}.

Bony *et al.* (2006), also cited by IPCC (2007), do not state a value for κ. However, they say –

"The Planck feedback parameter [equivalent to κ^{-1}] is negative (an increase in temperature enhances the long-wave emission to space and thus reduces *R* [the Earth's radiation budget]), and its typical value for the earth's atmosphere, estimated from GCM calculations (Colman 2003; Soden and Held 2006), is ~3.2 W m^2°K^{-1} (a value of ~3.8 W m^2°K^{-1} is obtained by defining [κ^{-1}]simply as $4\sigma T^3$, by equating the global mean outgoing long-wave radiation to σT^4 and by assuming an emission temperature of 255 °K)."

Bony takes $T_C \approx$ 255 °Kand $F_C \approx$ 235 W m^{-2} at Z_C as the theoretical basis for the stated *prima facie* value $\kappa^{-1} \approx T_C$ / $4F_C \approx$3.8 W m^2°K^{-1}, so that $\kappa \approx$ 0.263 °K W^{-1} m^2, in very close agreement with Hansen. However, Bony cites two further papers, Colman (2003) and Soden& Held (2006), as justification for the value $\kappa^{-1} \approx$ 3.2 W m^2°K^{-1}, so that $\kappa \approx$ 0.313 °K W^{-1} m^2.

Colman (2003) does not state a value for κ, but cites Hansen *et al.* (1984), rounding up the value $\kappa \approx$ 0.260 °K W^{-1} m^2 to 0.3 °K W^{-1} m^2 –

"The method used assumes a surface temperature increase of 1.2 °K with only the CO_2 forcing and the 'surface temperature' feedback operating (value originally taken from Hansen et al. 1984)."

Soden& Held (2006) likewise do not declare a value for κ. However, we may deduce their implicit central estimate $\kappa \approx$ 1 / 4 ≈ 0.250 °K W^{-1} m^2 from the following passage –

"The increase in opacity due to a doubling of CO2 causes [the characteristic emission level Z_C] to rise by ~150 meters. This results in a reduction in the effective temperature of the emission across the tropopause by ~(6.5K/km)(150 m) ≈ 1 K, which converts to 4 W m^{-2} using the Stefan-Boltzmann law."

Thus the IPCC cites only two papers that cite two others in turn. None of these papers provides any theoretical or empirical justification for a value as high as the $\kappa \approx$ 0.313 °K W^{-1} m^2 chosen by the IPCC.

Kiehl (1992) gives the following method, where $F_C$is total flux at Z_C:

$\kappa_S = T_S / (4F_C) \approx 288 / (4 \times 236) \approx 0.305$ °K W^{-1} m^2. (23)

Hartmann (1994) echoes Kiehl's method, generalizing it to any level J of an n-level troposphere thus:

$\kappa_J = T_J / (4F_C)$

$= T_J / [S(1 - \alpha)]$

$\approx T_J / [1368(1 - 0.31)] \approx T_J / 944$ °K W^{-1} m^2. (24)

Table 2 summarizes the values of κevident in the cited literature, with their derivations, *minorespriores*. The greatest value, chosen in IPCC (2007), is 30% above the least, chosen in IPCC (2001). However, because the feedback factor f depends not only upon the feedback-sum $b \approx$ 2.16 W m^{-2}°K^{-1}but also upon κ, the 30% increase in κ nearly doubles final climate sensitivity:

Table 2

Values of the "no-feedbacks" climate sensitivity parameter κ

Source	Value of κ	Ratio	How derived	$\lambda = \kappa(1 - 2.16\kappa)^{-1}$	Ratio
Ramanathan (1988), cited in IPCC (2001)	0.240 °K W^{-1} m^2	1.000	From λ = 0.500	0.500 °K W^{-1} m^2	1.000
Soden & Held (2006)	0.250 °K W^{-1} m^2	1.042	1 °K / 4 W m^{-2}	0.543 °K W^{-1} m^2	1.086
Hansen et al., (1984)[1]	0.260 °K W^{-1} m^2	1.083	1.25 / 4.8	0.593°K W^{-1} m^2	1.186
Bony et al. (2006)[1]	0.263 °K W^{-1} m^2	1.096	$(3.8)^{-1}$	0.609°K W^{-1} m^2	1.218
Bony et al. (2006)[2]	0.269 °K W^{-1} m^2	1.121	$T_C / [S(1-\alpha)]$	0.642°K W^{-1} m^2	1.284
Hansen et al., (1984)[2]	0.290 °K W^{-1} m^2	1.208	Hansen eqn. {14}	0.776 °K W^{-1} m^2	1.552
Colman (2003, appendix)	0.300 °K W^{-1} m^2	1.250	Rounded up	0.852 °K W^{-1} m^2	1.704
Kiehl (1992); Hartmann (1994)	0.305°K W^{-1} m^2	1.271	288 / (4 x 236)	0.894 °K W^{-1} m^2	1.788
Bony et al. (2006)[3]*, cited in IPCC (2007)*	0.313°K W^{-1} m^2	1.304	$(3.2)^{-1}$	0.966 °K W^{-1} m^2	1.932

The range of values for κ in the IPCC's assessment reports and in the papers which it cites is substantial. The value of κ implicit in IPCC (2007) is some 30% above that which is implicit in IPCC (2001): consequently, the value of the climate-sensitivity parameter λ is almost doubled. Though it is usual to assume a constant temperature lapse-rate, and hence to use the value of κ that obtains at the characteristic-emission level, where inbound and outbound radiative fluxes balance by definition, the theIPCC's current value for κ assumes that the lapse-rate increases as temperature rises. Also, the IPCC does not sufficiently allow for latitudinal asymmetry in distribution of the values of κ.

The value of *κ* cannot be deduced by observation, because temperature feedbacks are present and cannot be separately measured. However, it is possible to calculate *κ* using Eqn. (6), provided that the temperature change ΔT_λ, radiativeforcingsΔF_{2x}, and feedback-sum *b* over a given period are known. The years 1980 and 2005 will be compared, giving a spread of a quarter of a century. We take the feedback-sum b = 2.16 W m^{-2}°K^{-1} and begin by establishing values for ΔF and ΔT:

CO_2 concentration: 338.67 ppmv 378.77 ppmv ΔF = 5.35 ln (378.77/338.67) = **0.560 W m^{-2}**

Anomaly in T_S: 0.144 °K 0.557 °K ΔT = **0.412 °K** (NCDC)

Anomaly halved: ΔT = **0.206**°K (McKitrick) (25)

CO_2 concentrations are the annual means from 100 stations (Keeling & Whorf, 2004, updated). T_S values are NCDC annual anomalies, as five-year means centered on 1980 and 2005 respectively. Now, depending on whether the NCDC or implicit McKitrick value is correct, *κ*may be directly evaluated:

NCDC: $\kappa = \Delta T / (\Delta F + b\Delta T)$ = 0.412 / (0.560 + 2.16 x 0.412) = **0.284 °K W^{-1} m^2**

McKitrick: $\kappa = \Delta T / (\Delta F + b\Delta T)$ = 0.206 / (0.599 + 2.16 x 0.206) = **0.197 °K W^{-1} m^2**

Mean: κ = (0.284 + 0.197) / 2 = **0.241 °K W^{-1} m^2** (26)

We assume that Chylek (2008) is right to find transient and equilibrium climate sensitivity near-identical; that allof the warming from 1980-2005 was anthropogenic; that the IPCC's values for forcings and feedbacks are correct; and, in line 2, that McKitrick is right that the insufficiently-corrected heat-island effect of rapid urbanization since 1980 has artificially doubled the true rate of temperature increase in the major global datasets.

With these assumptions, κ is shown to be less, and perhaps considerably less, than the value implicit in IPCC (2007). The method of finding κ shown in Eqn. (24), which yields a value very close to that of IPCC (2007), is such that progressively *smaller* forcing increments would deliver progressively *larger* temperature increases at all levels of the atmosphere, contrary to the laws of thermodynamics and to the Stefan-Boltzmann radiative-transfer equation (Eqn. 18), which mandate the opposite.

It is accordingly necessary to select a value for κthat falls well below the IPCC's value. Dr. David Evans (personal communication, 2007) has calculated that the characteristic-emission-level value of κ should be diminished by ~10% to allow for the non-uniform latitudinal distribution of incoming solar radiation, giving a value near-identical to that in Eqn. (26), and to that implicit in IPCC (2001), thus –

$\kappa = 0.9T_C / [S(1 - \alpha)]$

$\approx 0.9 \times 254 / [1368(1 - 0.31)] \approx 0.242$ °K W^{-1} m^2 (27)

The feedback factor *f* reconsidered

The feedback factor *f* accounts for two-thirds of all radiative forcing in IPCC (2007); yet it is not expressly quantified, and no "Level Of Scientific Understanding" is assigned either to *f* or to the two variables *b* and κ upon which it is dependent.

Several further difficulties are apparent. Not the least is that, if the upper estimates of each of the climate-relevant feedbacks listed in IPCC (2007) are summed, an instability arises. The maxima are –

Water vapor feedback 1.98 W m^{-2} K^{-1}

Lapse rate feedback –0.58 W m^{-2} K^{-1}

Surface albedo feedback 0.34 W m^{-2} K^{-1}

Cloud albedo feedback 1.07 W m^{-2} K^{-1}

CO_2 feedback 0.57 W m^{-2} K^{-1}

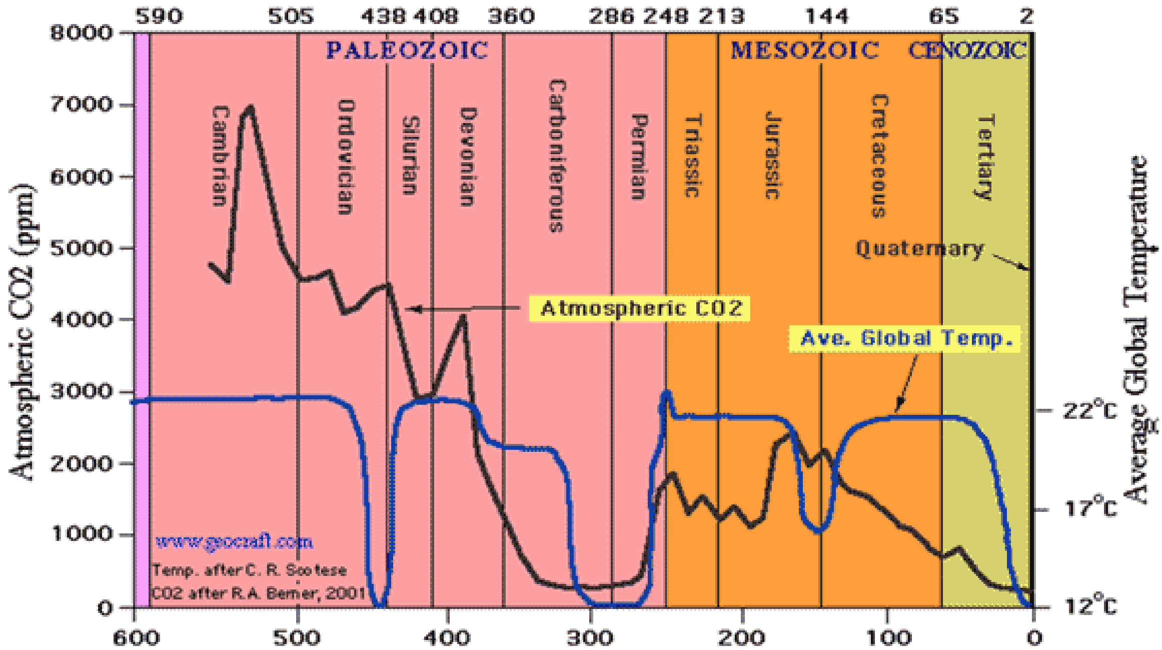
Total feedbacks *b* 3.38 W m^{-2} K^{-1} (28)

Since the equation $[f = (1 - b\kappa)^{-1}] \to \infty$ as $b \to [\kappa^{-1} = 3.2$ W m^{-2} $K^{-1}]$, the feedback-sum *b* cannot exceed 3.2 W m^{-2} K^{-1} without inducing a runaway greenhouse effect. Since no such effect has been observed or inferred in more than half a billion years of climate, since the concentration of CO_2 in the Cambrian atmosphere approached 20 times today's concentration, with an inferred mean global surface temperature no more than 7 °K higher than today's (Figure 7), and since a feedback-induced runaway greenhouse effect would occur even in today's climate where $b >= 3.2$ W m^{-2} K^{-1} but has not occurred, the IPCC's high-end estimates of the magnitude of individual temperature feedbacks are very likely to be excessive, implying that its central estimates are also likely to be excessive.

Figure 7

Fluctuating CO_2 but stable temperature for 600m years

Millions of years before present



Throughout the past 600 million years, almost one-seventh of the age of the Earth, the mode of global surface temperatures was ~22 °C, even when carbon dioxide concentration peaked at 7000 ppmv, almost 20 times today's near-record-low concentration. If so, then the instability inherent in the IPCC's high-end values for the principal temperature feedbacks has not occurred in reality, implying that the high-end estimates, and by implication the central estimates, for the magnitude of individual temperature feedbacks may be substantial exaggerations. ***Source:*** *Temperature reconstruction by C.R. Scotese; CO2 reconstruction after R.A. Berner; see also IPCC (2007).*

Since absence of correlation necessarily implies absence of causation, Figure 7 confirms what the recent temperature record implies: the causative link between changes in CO_2 concentration and changes in temperature cannot be as strong as the IPCC has suggested. The implications for climate sensitivity are self-evident. Figure 7 indicates that in the Cambrian era, when CO_2 concentration was ~25 times that which prevailed in the IPCC's reference year of 1750, the temperature was some 8.5 °C higher than it was in 1750. Yet the IPCC's current central estimate is that a mere doubling of CO_2 concentration compared with 1750 would increase temperature by almost 40% of the increase that is thought to have arisen in geological times from a 20-fold increase in CO_2 concentration (IPCC, 2007).

How could such overstatements of individual feedbacks have arisen? Not only is it impossible to obtain empirical confirmation of the value of any feedback by direct measurement; it is questionable whether the feedback equation presented in Bode (1945) is appropriate to the climate. That equation was intended to model feedbacks in linear electronic circuits: yet many temperature feedbacks – the water vapor and CO_2 feedbacks, for instance – are non-linear. Feedbacks, of course, induce non-linearity in linear objects: nevertheless, the Bode equation is valid only for objects whose *initial* state is linear. The climate is not a linear object: nor are most of the climate-relevant temperature feedbacks linear. The water-vapor feedback is an interesting instance of the non-linearity of temperature feedbacks. The increase in water-vapor concentration as the space occupied by the atmosphere warms is near-exponential; but the forcing effect of the additional water vapor is logarithmic. The IPCC's use of the Bode equation, even as a simplifying assumption, is accordingly questionable.

IPCC (2001: ch.7) devoted an entire chapter to feedbacks, but without assigning values to each feedback that was mentioned. Nor did the IPCC assign a "Level of Scientific Understanding" to each feedback, as it had to each forcing. In IPCC (2007), the principal climate-relevant feedbacks are quantified for the first time, but, again, no Level of Scientific Understanding" is assigned to them, even though they account for more than twice as much forcing as the greenhouse-gas and other anthropogenic-era forcings to which "Levels of Scientific Understanding" are assigned.

Now that the IPCC has published its estimates of the forcing effects of individual feedbacks for the first time, numerous papers challenging its chosen values have appeared in the peer-reviewed literature. Notable among these are Wentz *et al.* (2007), who suggest that the IPCC has failed to allow for two-thirds of the cooling effect of evaporation in its evaluation of the water vapor-feedback; and Spencer (2007),who points out that the cloud-albedo feedback, regarded by the IPCC as second in magnitude only to the water-vapor feedback, should in fact be negative rather than strongly positive.

It is, therefore, prudent and conservative to restore the values $\kappa \approx 0.24$ and $f \approx 2.08$ that are derivable from IPCC (2001), adjusting the values a little to maintain consistency with Eqn. (27). Accordingly, our revised central estimate of the feedback multiplier *f* is –

$f = (1 - b\kappa)^{-1} \approx (1 - 2.16 \times 0.242)^{-1} \approx 2.095$ (29)

Final climate sensitivity

Substituting in Eqn. (1) the revised values derived for the three factors in ΔT_λ, our re-evaluated central estimate of climate sensitivity is their product –

$\Delta T_\lambda = \Delta F_{2x}\, \kappa\, f \approx 1.135 \times 0.242 \times 2.095 \approx 0.58$ °K (30)

Theoretically, empirically, and in the literature that we have extensively cited, each of the values we have chosen as our central estimate is arguably more justifiable – and is certainly no less justifiable – than the substantially higher value selected by the IPCC. Accordingly, it is very likely that in response to a doubling of pre-industrial carbon dioxide concentration T_S will rise not by the 3.26 °K suggested by the IPCC, but by <1 °K.

Discussion

We have set out and then critically examined a detailed account of the IPCC's method of evaluating climate sensitivity. We have made explicit the identities, interrelations, and values of the key variables, many of which the IPCC does not explicitly describe or quantify. The IPCC's method does not provide a secure basis for policy-relevant conclusions. We now summarize some of its defects.

The IPCC's methodology relies unduly – indeed, almost exclusively – upon numerical analysis, even where the outputs of the models upon which it so heavily relies are manifestly and significantly at variance with theory or observation or both. Modeled projections such as those upon which the IPCC's entire case rests have long been proven impossible when applied to mathematically-chaotic objects, such as the climate, whose initial state can never be determined to a sufficient precision. For a similar reason, those of the IPCC's conclusions that are founded on probability distributions in the chaotic climate object are unsafe.

Not one of the key variables necessary to any reliable evaluation of climate sensitivity can be measured empirically. The IPCC's presentation of its principal conclusions as though they were near-certain is accordingly unjustifiable. We cannot even measure mean global surface temperature anomalies to within a factor of 2; and the IPCC's reliance upon mean global temperatures, even if they could be correctly evaluated, itself introduces substantial errors in its evaluation of climate sensitivity.

The IPCC overstates the radiative forcing caused by increased CO_2 concentration at least threefold because the models upon which it relies have been programmed fundamentally to misunderstand the difference between tropical and extra-tropical climates, and to apply global averages that lead to error.

The IPCC overstates the value of the base climate sensitivity parameter for a similar reason. Indeed, its methodology would in effect repeal the fundamental equation of radiative transfer (Eqn. 18), yielding the impossible result that at every level of the atmosphere ever-smaller forcings would induce ever-greater temperature increases, even in the absence of any temperature feedbacks.

The IPCC overstates temperature feedbacks to such an extent that the sum of the high-end values that it has now, for the first time, quantified would cross the instability threshold in the Bode feedback equation and induce a runaway greenhouse effect that has not occurred even in geological times despite CO_2 concentrations almost 20 times today's, and temperatures up to 7 ºC higher than today's.

The Bode equation, furthermore, is of questionable utility because it was not designed to model feedbacks in non-linear objects such as the climate. The IPCC's quantification of temperature feedbacks is, accordingly, inherently unreliable. It may even be that, as Lindzen (2001) and Spencer (2007) have argued, feedbacks are net-negative, though a more cautious assumption has been made in this paper.

It is of no little significance that the IPCC's value for the coefficient in the CO_2 forcing equation depends on only one paper in the literature; that its values for the feedbacks that it believes account for two-thirds of humankind's effect on global temperatures are likewise taken from only one paper; and that its implicit value of the crucial parameter κ depends upon only two papers, one of which had been written by a lead author of the chapter in question, and neither of which provides any theoretical or empirical justification for a value as high as that which the IPCC adopted.

The IPCC has not drawn on thousands of published, peer-reviewed papers to support its central estimates for the variables from which climate sensitivity is calculated, but on a handful.

On this brief analysis, it seems that no great reliance can be placed upon the IPCC's central estimates of climate sensitivity, still less on its high-end estimates. The IPCC's assessments, in their current state, cannot be said to be "policy-relevant". They provide no justification for taking the very costly and drastic actions advocated in some circles to mitigate “global warming”, which Eqn. (30) suggests will be small (<1 °C at CO_2 doubling), harmless, and beneficial.

Conclusion

Even if temperature had risen above natural variability, the recent solar Grand Maximum may have been chiefly responsible. Even if the sun were not chiefly to blame for the past half-century’s warming, the IPCC has not demonstrated that, since CO_2 occupies only one-ten-thousandth part more of the atmosphere that it did in 1750, it has contributed more than a small fraction of the warming. Even if carbon dioxide were chiefly responsible for the warming that ceased in 1998 and may not resume until 2015, the distinctive, projected fingerprint of anthropogenic “greenhouse-gas” warming is entirely absent from the observed record. Even if the fingerprint were present, computer models are long proven to be inherently incapable of providing projections of the future state of the climate that are sound enough for policymaking. Even if *per impossibile*the models could ever become reliable, the present paper demonstrates that it is not at all likely that the world will warm as much as the IPCC imagines. Even if the world were to warm that much, the overwhelming majority of the scientific, peer-reviewed literature does not predict that catastrophe would ensue. Even if catastrophe might ensue, even the most drastic proposals to mitigate future climate change by reducing emissions of carbon dioxide would make very little difference to the climate. Even if mitigation were likely to be effective, it would do more harm than good: already millions face starvation as the dash for biofuels takes agricultural land out of essential food production: a warning that taking precautions, “just in case”, can do untold harm unless there is a sound, scientific basis for them. Finally, even if mitigation might do more good than harm, adaptation as (and if) necessary would be far more cost-effective and less likely to be harmful.

In short, we must get the science right, or we shall get the policy wrong. If the concluding equation in this analysis (Eqn. 30) is correct, the IPCC’s estimates of climate sensitivity must have been very much exaggerated. There may, therefore, be a good reason why, contrary to the projections of the models on which the IPCC relies, temperatures have not risen for a decade and have been falling since the phase-transition in global temperature trends that occurred in late 2001. Perhaps real-world climate sensitivity is very much below the IPCC’s estimates. Perhaps, therefore, there is no “climate crisis” at all. At present, then, in policy terms there is no case for doing anything. The correct policy approach to a non-problem is to have the courage to do nothing.

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