Has the IPCC inflated the feedback factor?
By
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Guest Blog for Climate Science: Roger Pielke Sr. Research Group News

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In the IPCC’s methodology, climate sensitivity $\Delta T$ to radiative forcing is the product of three factors:

1. Tropopausal radiative forcing $\Delta F$

$$\Delta F \approx 5.35 \ln(C/C_0) \implies \Delta F_{2x} \approx 5.35 \ln 2 \quad \text{W m}^{-2}, \quad (1)$$

where $(C/C_0)$ is a proportionate increase in CO$_2$ concentration and, specifically, $\Delta F_{2x} \approx 3.708$ W m$^{-2}$ is the radiative forcing at CO$_2$ doubling. For simplicity, no significant error will arise here if it is assumed that all other anthropogenic forcings are slightly net-negative, so that $\Delta F_{2x} \approx 5 \ln 2 \approx 3.466$ W m$^{-2}$.

2. The no-feedbacks climate sensitivity parameter $\kappa$

$$\kappa = \Delta T_\kappa / \Delta F = \Delta T_\lambda / (\Delta F + b\Delta T_\lambda) \quad \text{°K W}^{-1} \text{ m}^2, \quad (2)$$

where $\Delta T_\kappa$ is the temperature response to forcings only, without feedbacks; $\Delta T_\lambda$ is the temperature change in response to forcings plus feedbacks; and $b$ is the sum in W m$^{-2}$ °K$^{-1}$ of all unamplified temperature feedbacks. The key parameter $\kappa$ is not mentioned in IPCC (2007), and no error-bars are given. The value $\kappa \approx 0.313$ °K W$^{-1}$ m$^2$ implicit in IPCC (2007) is the reciprocal of the “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 $(\lambda_1 + \lambda_2 + ... \lambda_n).$” (IPCC, 2007: ch.8, footnote)

3. The feedback multiplier $f$

$$f = (1 - b\kappa)^{-1}. \quad (3)$$

This unitless variable is evaluated in IPCC (2007, ch.8) using the feedback-amplification function given in Bode (1945). First, we note the dependence of $f$ not only upon $b$ but also upon $\kappa$ –

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

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

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

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

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

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

$$\approx (1 - b / 3.2)^{-1}$$

$$\implies \kappa \approx 3.2^{-1}$$

$$\approx 0.313 \quad \text{°K W}^{-1} \text{ m}^2, \quad (4)$$
Equivalently, expressing the feedback loop as the sum of an infinite series,

\[
\Delta T = \Delta F \kappa + \Delta F \kappa^2 b + \Delta F \kappa^2 b^2 + \ldots
\]

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

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

\[
= \Delta F \kappa f
\]

\[
\Rightarrow \lambda = \Delta T / \Delta F = \kappa f
\]

\[
(5)
\]

**Figure 1**

**How climate feedbacks feed back**

**Upper left panel:** A forcing \(dF\) is input (by multiplication) to the climate sensitivity parameter \(\lambda\), yielding \(dT\) as the output. **Lower left panel:** The forcing \(dF\) is input to the no-feedbacks climate sensitivity parameter \(\kappa\), successively amplified by temperature feedbacks summing to \(b\). **Right panel:** The full diagram illustrates the impact of individual climate feedbacks, together with \(\kappa\), so that \(\lambda = \kappa f\).

Diagrams follow kind suggestions by Dr. David Evans.

Next, \(b\) must be evaluated. IPCC (2007) quantifies the principal temperature feedbacks individually for the first time:

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

To these we add the CO\(_2\) feedback, which IPCC (2007, ch.7) separately expresses not as \(\text{W m}^{-2} \text{K}^{-1}\) 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

\[o = (p + q) / p = (556 + 87) / 556 \approx 1.16\]. Then the CO\(_2\) feedback is

\[
\lambda_{\text{CO}_2} = z \ln(o) / dT_\lambda \approx 5.35 \ln(1.16) / 3.2 \approx 0.25 \text{ W m}^{-2} \text{K}^{-1}.
\]

(6)
The CO\textsubscript{2} feedback completes the feedback-sum \(b\):

\[
b = 1.8 - 0.84 + 0.26 + 0.69 \pm 0.25 \approx 2.16 \text{ W m}^{-2} \text{K}^{-1}.
\]  

(7)

From \(\kappa = 0.313\) and \(b = 2.16\), a central estimate of the value of the feedback factor \(f\) is –

\[
f = (1 - b\kappa)^{-1} \approx (1 - 2.16 \times 0.313)^{-1} \approx 3.077
\]

(8)

This result is broadly consistent with Hansen \textit{et al.} (1984), where \(f = 3-4\) is suggested.

**Final climate sensitivity** \(\Delta T_\lambda\), after taking account of feedbacks, is the product of the three factors we have briefly considered –

\[
\Delta T_\lambda = \Delta F_\lambda = \Delta F \kappa f = \Delta F \kappa (1 - \kappa b)^{-1} \text{ °K},
\]

(9)

where \(\lambda = \kappa f\) is the with-feedbacks climate sensitivity parameter. Thus, at CO\textsubscript{2} doubling, –

\[
\Delta T_\lambda = \Delta F_{2x} \kappa f \approx 3.466 \times 0.313 \times 3.077 \approx 3.3 \text{ °K}
\]

(10)

IPCC (2007) gives \(dT_\lambda\) on [2.0, 4.5] °K at CO\textsubscript{2} doubling, with a central estimate \(dT_\lambda \approx 3.2\) °K, to which the value \(dT_\lambda \approx 3.3\) °K in equation (10) is sufficiently close to demonstrate that the IPCC’s method has been reasonably replicated.

**The feedback factor reconsidered**

The feedback factor \(f\) accounts for at least 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 \(\kappa\) upon which it is dependent.

Several difficulties are apparent.

Not the least of these difficulties 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 1.98, lapse rate –0.58, surface albedo 0.34, cloud albedo 1.07, CO\textsubscript{2} 0.57, total \(4.54\) W m\(^{-2}\) K\(^{-1}\).

The equation \(f = (1 - b\kappa)^{-1}\) becomes unstable as \(b \to \kappa^{-1} = 3.2\) W m\(^{-2}\) K\(^{-1}\). Yet, if each of the individual feedbacks imagined by the IPCC is increased by less than half the interval between the IPCC’s central estimate and its maximum, an instability or “runaway greenhouse effect” is reached.

Yet it is reliably inferred from palaeoclimatological data that no “runaway greenhouse effect” has occurred in the half billion years since the Cambrian era, when atmospheric CO\textsubscript{2} concentration peaked at almost 20 times today’s value, as Figure 2 shows:
Timeline of climate stability: Throughout the past 600 million years, almost one-seventh of the age of the Earth, global mean surface temperatures are thought not to have exceeded a plateau in the region of 22 °C, even when carbon dioxide concentration peaked at 7000 ppmv, almost 20 times today’s near-record-low concentration. If the graph is correct, then the instability inherent in the IPCC’s error-bars for the principal temperature feedbacks has not occurred in reality, suggesting that the IPCC’s estimates may be substantial exaggerations.

Given the stability of the climate over the past half billion years, there is little danger that current anthropogenic perturbation of the climate will cause a “runaway greenhouse effect”. It is likely, therefore, that the IPCC’s current estimates of the magnitude of climate feedbacks have been substantially exaggerated.

To verify the likelihood that the IPCC is according too large a role to climate feedbacks, comparisons were made between the 2007 report and the two previous reports, in 1995 and 2001 respectively.

### Table 1
**Falling forcing coefficient, rising temperature response**

<table>
<thead>
<tr>
<th>IPCC</th>
<th>Z</th>
<th>$\ln 2 = dF_{2x}$</th>
<th>Sens.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1995</td>
<td>6.40</td>
<td>4.44 Wm$^{-2}$</td>
<td>2.5 °K</td>
</tr>
<tr>
<td>2001</td>
<td>5.35</td>
<td>3.71 Wm$^{-2}$</td>
<td>3.0 °K</td>
</tr>
<tr>
<td>2007</td>
<td>5.00</td>
<td>3.47 Wm$^{-2}$</td>
<td>3.2 °K</td>
</tr>
</tbody>
</table>

Table 1 shows that, although the estimated forcing effect of CO$_2$ has been reduced by more than one-fifth in 12 years, climate sensitivity has risen by a quarter. The sole reason for this increase is feedback inflation, as Figure 3 shows:
Holding $\kappa$ constant and taking the IPCC’s changing central estimates $\Delta T_\lambda$ and $\Delta F_{2x}$, it is possible to calculate that the IPCC has increased its central estimate of the value of the feedback factor $f$ by more than two-thirds in the 12 years since 1995. Yet the IPCC’s reports do not explicitly draw the reader’s attention to, still less justify, the magnitude of this “feedback inflation”.

Indeed, in IPCC (2007) the stated values for the feedbacks that account for more than two-thirds of humankind’s imagined effect on global temperatures are taken from a single paper. The value of the coefficient $z$ in the CO$_2$ forcing equation likewise depends on only one paper. The implicit value of the crucial parameter $\kappa$ 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 the IPCC’s chosen value. The notion that the IPCC has drawn on thousands of published, peer-reviewed papers to support its central estimates for the variables from which climate sensitivity is calculated is not supported by the evidence.

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 quantification 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.

In these circumstances, it is not unreasonable to readopt the value $b = 1.43$ which, inferentially, was the central estimate in IPCC (1995). Holding the values of $\Delta F_{2x}$ and $\kappa$ constant, climate sensitivity falls by more than one-third –

$$\Delta T_\lambda = \Delta F_{2x} \kappa f \approx 3.466 \times 0.313 \times 1.808 \approx 2.0 \, ^\circ\text{K}$$

(11)
If the value of $\kappa$ were reduced by as little as one-eighth so as better to reflect the range of values actually stated in the papers cited by the IPCC, climate sensitivity would fall still further –

$$\Delta T_\lambda = \Delta F_{2x} \kappa f \approx 3.466 \times 0.277 \times 1.656 \approx 1.6 \, ^\circ K$$  \hspace{1cm} (12)$$

Finally, if, as Lindzen (2008) has suggested, all terrestrial forcings were cut by two-thirds to take account of the absence of the altitudinal difference in decadal warming rates in the tropics that is predicted in all of the models on which the IPCC relies but has not been observed in half a century of radiosonde observations and 30 years of satellite records (Douglass et al., 2007), climate sensitivity would again decline –

$$\Delta T_\lambda = \Delta F_{2x} \kappa f \approx 1.155 \times 0.277 \times 1.656 \approx 0.5 \, ^\circ K$$  \hspace{1cm} (13)$$

It is not for a non-climatologist such as me to say which climate-sensitivity value is correct. On this brief analysis, however, it is evident that the models on which the IPCC relies are little better than expensive guesswork, and that no great reliance can be placed upon the IPCC’s central estimates, still less on its high-end estimates. As a policymaker, I should be profoundly reluctant, given the current state of the science, to recommend to Ministers that they should take the drastic actions advocated in some circles to mitigate “global warming”.

Setting aside the self-evident truth that adaptation as (and if) necessary would be orders of magnitude more cost-effective than mitigation, a conclusion that tends to be overlooked as a result of the IPCC’s bizarre decision to establish separate working groups to consider adaptation and mitigation, the simple calculations in this paper have demonstrated a strong likelihood that the IPCC’s estimates of climate sensitivity are prodigiously exaggerated; that there may be a good reason why, contrary to all the projections of the IPCC’s models, temperatures have not risen for a decade and have been falling since the phase-transition in global temperature trends that occurred in late 2001 (see Figure 3); and that there is no “climate crisis” at all.

Figure 3
“Global warming”?
Get *Apocalypse? NO!*, the fast-paced, fact-packed, feature-length movie that puts Al Gore in his place and the climate scare in perspective, at:

http://scienceandpublicpolicy.org/apocalypseno-dvd.html