Climate Scientists Misapplied Basic Physics — A Summary

A mistake in the climate model architecture changes everything—heat trapped by extra carbon dioxide just reroutes to space from water vapor

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Project home: sciencespeak.com/climate-basic.html

See the Synopsis for more a detailed version (24 pages).

Dr David Evans earned six degrees related to modeling and applied mathematics over ten years, including a PhD from Stanford University. He was instrumental in building the carbon accounting system Australia uses to estimate carbon changes in its biosphere, for the Australian Greenhouse Office.

- Until now, skeptics have pointed to discrepancies between climate models and reality, and have questioned the values of the basic physics parameters (the amount of outgoing heat blocked by increasing CO_2, total feedbacks, and the Planck sensitivity).
- But CO_2 theory is impregnable in the minds of most warmists because of "basic physics", or more precisely, their application of physics to climate, the forcing-feedback model.
- The *architecture* of the "basic physics", the way the parameters are combined to calculate the sensitivity to CO_2, was recently discovered to be severely flawed. This is novel.
- The assumption that led to the mistake in the climate model architecture was made in the first estimate of sensitivity to CO_2, back in1896, to overcome inadequate climate data. It became "baked into the cake" of climate science, an intrinsic part of the paradigm.
- The errant assumption is that the blocking of some heat to space by increasing CO_2 *causes the same surface warming* as the same amount of extra absorbed sunlight. The conventional basic model calculates the warming due to extra CO_2 as if it were extra sunlight. Ever since, climate scientists have convinced themselves that a decrease in heat outflow is equivalent to an increase in heat inflow—which while true for the total heat on the planet, is not relevant to how much extra heat is emitted from the surface (as opposed to water vapor, CO_2, and cloud tops), which is what determines surface warming.
- Accepting the IPCC parameter values but repairing the architecture, and using modern climate data, shows that future warming due to CO_2 will be a fifth to a tenth of official estimates. Less than 20% of the global warming since 1973 was due to increasing CO_2.

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1 Introduction

This document summarizes a series of blog posts where this work debuted for public scrutiny. The blog posts are based on a scientific paper, currently undergoing peer review.

1.1 Significance of the Forcing-Feedback Model (FFM)

This document focuses on the forcing-feedback model (FFM) of climate. It is the conventional sensitivity model for estimating the Earth's sensitivity to CO_2. Predating computer simulations, it is the application of "basic physics" to the climate.

The idea that "it's the physics" makes the CO_2 theory impregnable in the minds of the establishment. They remain convinced that increasing carbon dioxide causes dangerous warming essentially because of the FFM, rather than because of the huge opaque computer models. They are so convinced by the FFM that, for them, it overrides empirical evidence—discordant empirical evidence is presumed to be somehow wrong.

The FFM ignited concern about carbon dioxide; without it we probably wouldn't be too worried. The Charney Report of 1979, the seminal document that ushered in the current era of concern about carbon dioxide, presents the FFM as its first argument. The FFM is ubiquitous in climate science, embedded in the conversation. Its ideas underlie all of establishment climate science; it's the basic mental model, so pervasive that one might overlook it because it is everywhere. One can construct the FFM just from what "everyone knows" in climate science. Yet it does not have a formal name, perhaps because it has been omnipresent for decades, since the birth of modern climate science. Here we've called it the "forcing-feedback model" (FFM) so it can be discussed explicitly.

There is no empirical evidence that rising levels of carbon dioxide will raise the temperature of the Earth's surface as fast as the UN's Intergovernmental Panel on Climate Change (IPCC) predicts. The predictions are entirely based on calculations with models.

1.2 Road Map

The FFM consists of three parameter values, and an architecture that ties them together. Until now critics have almost exclusively queried the parameter values, but here we accept all the conventional parameter values in the IPCC's Fifth Assessment Report (AR5). Examining the architecture, we find two major flaws. We modify the architecture of the conventional model to fix those flaws. Fitting climate data to the alternative basic model finds that the sensitivity to CO_2 is an order of magnitude lower than estimated by the FFM and the IPCC. The alternative model also resolves the empirical data over the tropical hotspot.

Terminology is colored red when introduced, to make it easier to find.

2 Energy Balance

In basic climate models, the incoming energy is equal to the outgoing energy. Thus they are only for the transition of Earth from one steady-state to another, and can only be applied between endpoints that are assumed close to steady state.

A variable (e.g. X) in the initial steady-state has a "0" subscript (e.g. X_0), while the change from the initial to the final steady-state is prefixed with a "Δ" (e.g. ΔX). In steady state the outgoing long-wave radiation (OLR) R matches the absorbed solar radiation (ASR) A,

$$A = R, \tag{1}$$

in what is known as "energy balance" or "radiation balance" (both are ~239 W m^{-2}). Thus

$$\Delta A = \Delta R. \tag{2}$$

3 The Forcing-Feedback Model (FFM)

3.1 The Three Parameters

3.1.1 The Decrease in OLR from Carbon Dioxide when CO_2 Doubles

An increasing atmospheric concentration of CO_2 reduces the amount of OLR emitted by CO_2, by an amount proportional to the base-2 logarithm L of the CO_2 concentration C. The decrease in OLR emitted by CO_2 molecules per doubling of the CO_2 concentration, when everything else is held constant, is (AR5, p. 8SM-7)

$$D_{\mathrm{R,2X}} = -\frac{\partial R}{\partial L} = 3.7\,[3.5, 4.1]\ \mathrm{W\,m^{-2}}. \tag{3}$$

3.1.2 The Planck Sensitivity

The increase in the average surface temperature of the Earth T_S as the net downward flux from the top of the atmosphere increases, but everything else is held constant, is

$$\lambda_0 = \frac{1}{\partial R / \partial T_S} \simeq \frac{1}{3.2 \pm 0.1} = 0.31 \pm 0.01\ \mathrm{^\circ C\,W^{-1}\,m^2}, \tag{4}$$

where the value of its reciprocal is $3.2 \pm 0.1\ \mathrm{W\,m^{-2}\,^\circ C^{-1}}$ (AR5, p. 818) (which is the increase in OLR as the surface warms, called the "Planck feedback", though it is not really a feedback because it does not affect what causes it).

3.1.3 The Total Feedback

The increase in net downward flux from the top of the atmosphere in response to surface warming is the total feedback

$$f = 1.7\,[0.97, 2.43]\ \mathrm{W\,m^{-2}\,^\circ C^{-1}}. \tag{5}$$

AR5 (Table 9.5 and Fig. 9.43, and p. 591) reports the individual and total feedbacks from the CMIP5, in W m^{-2} °C^{-1}: water vapor +1.6±0.3, lapse rate −0.6±0.4, water vapor and lapse rate combined +1.1±0.2, surface albedo +0.3±0.1, cloud +0.3±0.7.

3.2 The Architecture

The FFM is just a radiation balance. (It is derived here and here, based on the leading climate textbook and a paper by leading climate theorists.) The radiation imbalances ("forcings") caused by the various climate drivers are calculated, and then added to form the total radiative imbalance. Then the model calculates the surface warming required to increase the OLR by just enough to restore the radiation to balance, after taking the feedbacks to surface warming into account. The model architecture is shown in Fig. 1.

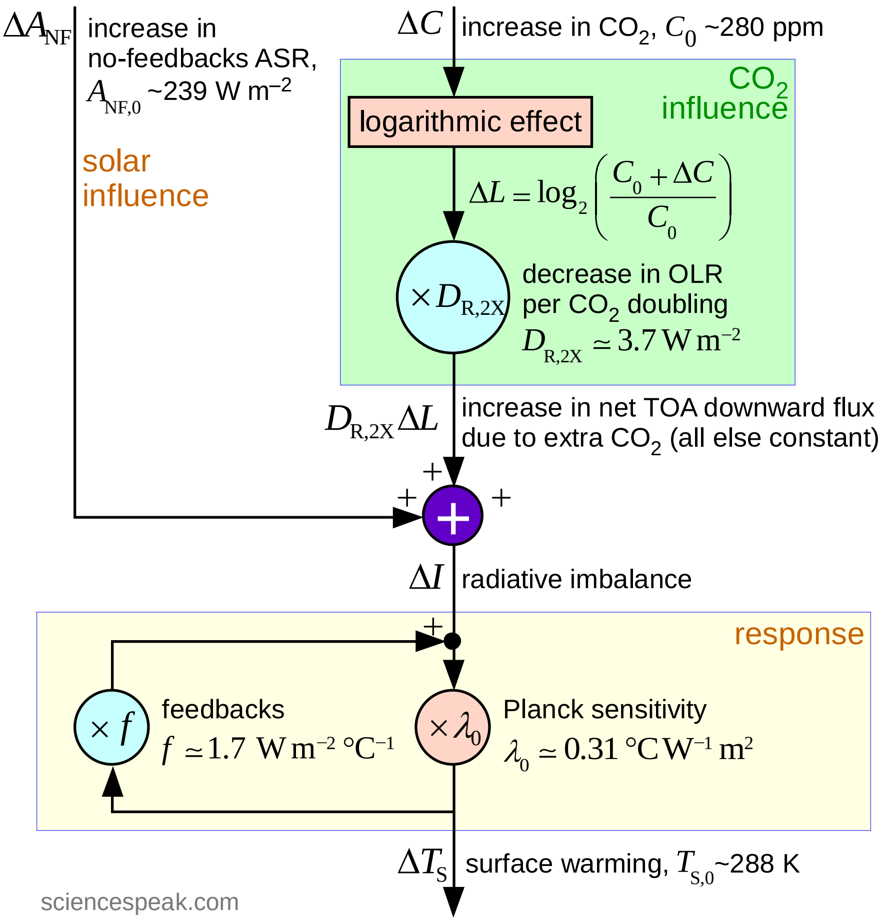

Figure 1: The forcing-feedback model (FFM) of climate, for the two main drivers: increased ASR (other than due to feedbacks in response to surface warming) and increased CO_2.

The surface warming, by inspection of Fig. 1, is

$$\Delta T_S = \Delta I \lambda_0 \left[1 + f\lambda_0 + (f\lambda_0)^2 + \ldots\right] = \frac{\lambda_0}{1 - f\lambda_0}\Delta I = \frac{\lambda_0}{1 - f\lambda_0}\left(\Delta A_{NF} + D_{R,2X}\Delta L\right). \quad (6)$$

3.3 Estimating the ECS

The equilibrium climate sensitivity (ECS) is the surface warming when the CO_2 concentration doubles (i.e. ΔL is one) and other drivers are unchanged:

$$\text{ECS} = \frac{\lambda_0}{1 - f\lambda_0} D_{\text{R,2X}} = \frac{D_{\text{R,2X}}}{\lambda_0^{-1} - f} \simeq \frac{3.7\,[3.5, 4.1]}{3.2 \pm 0.1 - 1.7\,[0.97, 2.43]} \simeq 2.5[1.24, 3.7]\ °\text{C}. \qquad (7)$$

This accords with AR5 (p. 1033, p.1451–2), which finds the ECS as likely to be 1.5°C to 4.5°C for a doubling of equivalent CO_2 concentration. Setting *f* to zero in Eq. (7) gives the no-feedbacks-ECS, namely $1.16[1.08, 1.29]\ °\text{C}$.

3.4 Major Architectural Errors

3.4.1 Omits Feedbacks other than to Surface Warming

The architecture in Fig. 1 only includes feedbacks in response to surface warming. If there exists a feedback which responds to a climate driver, but is not triggered by some other driver or the surface warming it causes, then there is literally no place for it in the conventional architecture—it is omitted. A feedback that is specific to a particular climate driver would not be triggered by other climate drivers or by the surface warming they caused, so such a feedback is *not* a response to surface warming.

3.4.2 Solar Response Applied to all Climate Drivers

The architecture in Fig. 1 summarizes the effect of all the various climate drivers in a single number, the radiative imbalance ΔI. Thus, as far as the calculation of surface warming is concerned, any climate driver is interchangeable with any other climate driver that produces the same radiative imbalance (forcing).

The model treats the radiative imbalance due to any climate driver by the identical response, namely the Planck sensitivity coupled with feedbacks to surface warming—multiplication by $\lambda_0/(1 - f\lambda_0)$. The Planck sensitivity is the surface warming associated with a change in OLR or ASR while everything about the climate is kept constant, then the feedbacks allow everything to change in response to the surface warming. Hence the response that is applied to all the climate drivers is the "solar response"—the surface warming for an increase in ASR (ΔA_{NF} to be more precise), in °C per W m^{-2}.

The "CO_2 response", the surface warming due to an increase in CO_2 forcing in °C per W m^{-2}, is quite distinct from the solar response:

Response to More ASR (the "solar response")	Response to More CO_2 (the "CO_2 response")
Increases OLR	OLR unchanged[2] (redistributes OLR between emitters)
Adds energy to the climate system	Blocks energy from leaving the climate system
Occurs mainly at the surface	Occurs mainly in the upper troposphere

Table 1: The differences between the solar and CO_2 responses are substantial.

While a decrease in heat outflow is equivalent to a matching increase in heat inflow in terms of the amount of heat on the planet, it is not necessarily equivalent in terms of how the outgoing heat is distributed between the various emitters (water vapor, CO_2, cloud tops, the sur-

[2] Ignoring the minor effect of surface albedo feedback in response to surface warming.

face, etc.). Surface warming is determined only by the change in emissions from the surface—because a hotter surface emits more to space.

The assumption: *the surface warming due to increased* CO_2 *is the same as the surface warming due to the increased absorbed sunlight that causes the same forcing.* This was a convenient assumption because it made the problem of estimating sensitivity to CO_2 tractable—the effect of extra absorbed sunlight could be estimated, in large part by the Stefan-Boltzmann equation. Notice that this assumption is intrinsic to the architecture of the FFM (Fig. 1). It seems *especially* unlikely to be true given that the total emitted heat is different.

The FFM applies the solar response to the influence of increased CO_2—but how realistic can that be? Not very, it turns out, as we show using modern climate data.

4 The Rerouting Feedback

The "rerouting feedback" is proposed. It is a feedback that is specifically in response to increased CO_2; it is part of the CO_2 response but not a response to surface warming.

4.1 The Feedback

Increasing the CO_2 concentration warms the upper troposphere, because the emissions spectrum changes and there is more warming by downward emissions from the extra CO_2. This heats neighboring molecules, including water vapor molecules in the water vapor emissions layer (WVEL) and some cloud tops, so more OLR is emitted by water vapor molecules and cloud tops. (The WVEL is the optical top band of water molecules that can emit to space—upwards emissions by water vapor molecules beneath the top layer are absorbed by water vapor molecules higher up. While usually in the upper troposphere, it moves up and down as water vapor moves within the atmosphere.)

The WVEL emits more so it must be at a higher average temperature, due to a combination of warming by increased CO_2 and a decline in average height moving it to a warmer altitude.

4.2 Causes the WVEL to Descend

Upper tropospheric warming by increased CO_2 distorts the local lapse rate, which becomes less steep (less cooling per km of rise). The atmosphere around the WVEL altitude becomes warmer and more stable. The moist air rising by convection thus rises less vigorously and not as high, and so the average height of the WVEL declines. Because increasing CO_2 lowers the vigor of convection in the upper troposphere, humidity builds up and clouds condense at lower levels, suggesting the average height of the cloud tops declines.

This explanation of the lowering of the WVEL by the rerouting feedback relies only on the altered movements of water vapor due to increased CO_2, rather than on radiation transfer.

4.3 Comments

It is called the "rerouting feedback" because some fraction of the OLR that is blocked by rising CO_2 levels from escaping to space from CO_2 molecules is *rerouted* to space via emission from water vapor and cloud tops instead.

This rerouting takes place high in the atmosphere, far from the surface, so there is no place for it in the FFM—it is in the blindspot of that model, which contains only feedbacks in response to surface warming.

The heat rerouted to space via water vapor molecules is not available to travel down and warm the surface, as in the conventional models. Thus the rerouting feedback reduces the impact of increasing CO_2 on surface warming. If this feedback is real and significant, it could help explain why CO_2 is not as potent as the IPCC supposes.

5 The Alternative Sensitivity Model

5.1 Fixes

5.1.1 Each Climate Driver Needs its own Specific Feedbacks and Response

The appropriate response must be applied to the forcing due to each climate driver. So a driver-specific response, including any driver-specific feedbacks, calculates the surface warming ("warming") due to that driver. The warmings thus calculated are added together to form the total surface warming, because the climate is approximately linear for the small temperature perturbations involved in global warming—the effects of a driver on other drivers are assumed to be second order. The CO_2 response is assumed proportional to CO_2 forcing, so the response is to multiply the CO_2 forcing by the CO_2 sensitivity λ_C .

This solves both major architectural errors in the FFM. Note the paradigm shift: the conventional model adds forcings, while the alternative model adds warmings.

5.1.2 Retaining the Radiation Balance

Radiation must balance (Eq. (2)), but this is no longer guaranteed merely by the connections in the model. However radiation balance in the model is ensured by setting the increase in ASR ΔA, where it occurs in the model, equal to the increase in OLR ΔR, which must be obtained by some other means.

ΔA is the increase in no-feedbacks-ASR, ΔA_{NF}, plus the increase in albedo in response to surface warming, namely $f_\alpha \Delta T_S$, so the model must explicitly form that sum. This leaves just the non-albedo feedbacks $f_{\bar{\alpha}}$ in the feedback loop inside the solar response. (The total feedback f is partitioned into albedo f_α and non-albedo feedbacks $f_{\bar{\alpha}}$, where f equals $f_\alpha + f_{\bar{\alpha}}$.)

5.2 The Sum of Warmings Sub-Model

Applying the two fixes above to the FFM of Fig. 1 produces the sum-of-warmings model in Fig. 2.

The alternative and conventional basic models differ by only one connection: if the CO_2 forcing $D_{R,2X} \Delta L$ in Fig. 2 is disconnected from the CO_2 response and instead added to the node that adds ΔA_{NF} to $f_\alpha \Delta T_S$, then Fig. 2 becomes the same model as in Fig. 1. Hence the alternative and conventional models are fundamentally different—they cannot both be correct (unless the CO_2 and solar responses are equally strong, that is, λ_C equals $\lambda_0 / (1 - f_{\bar{\alpha}} \lambda_0)$).

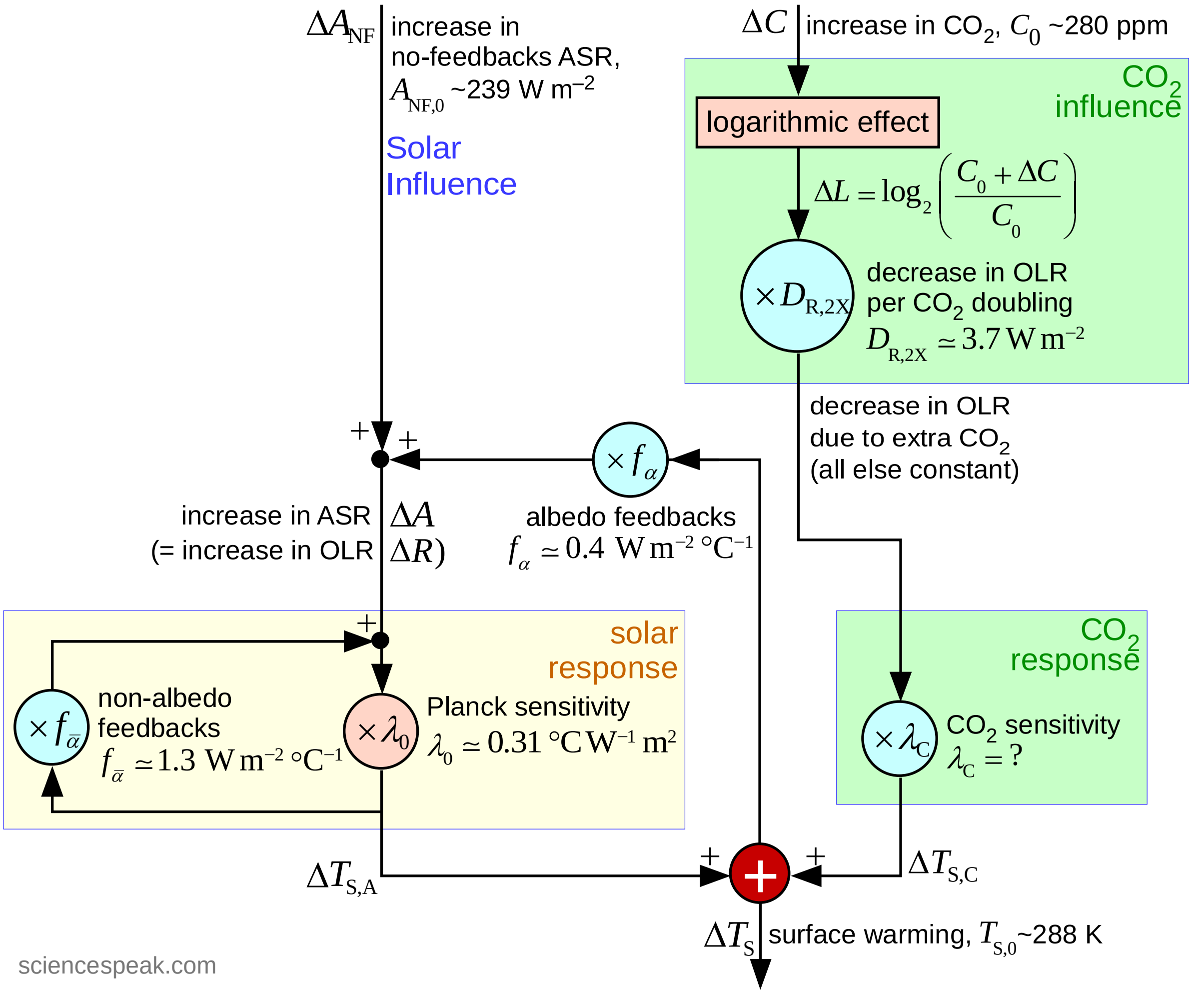

Figure 2: The sum-of-warmings model. The alternative sensitivity model combines this model and an OLR model, by setting the increase in ASR here equal to the increase in OLR computed by the OLR model.

5.3 The OLR Sub-Model

The alternative model needs an estimate of the increase in OLR, for radiation balance. The increase in OLR over an observed period is estimated using an OLR model whose inputs are the changes in the parameters of the main emissions layers. This drags a lot more data into the calculation of the sensitivity to CO_2, but it is perhaps the simplest way of determining the actual OLR, or at least bounding it. The OLR model is in this spreadsheet, and is developed here, here, here, and here.

The increase in OLR is modelled as

$$\Delta R = \tau \Delta T_S + \theta_W \Delta h_W + \theta_U \Delta h_U + g\Delta\Gamma + D_\beta \Delta\beta + \theta_M \Delta h_M - D_{R,2X}\Delta L \quad (8)$$

where

- h_W, h_U, and h_M are the average heights of the WVEL, the cloud tops, and the methane emission layer, respectively; $h_{W,0} \simeq 8\,\mathrm{km}$, $h_{U,0} \simeq 3.3\,\mathrm{km}$, $h_{M,0} \simeq 3\,\mathrm{km}$
- Γ is the average lapse rate; $\Gamma_0 \simeq 6.5\ \mathrm{°C\,km^{-1}}$
- β is the cloud fraction; $\beta_0 \simeq 62\%$

and

$$\begin{aligned} \tau &\simeq 3.2\ \mathrm{W\,m^{-2}\,{}^\circ C^{-1}} & g &\simeq -13.5\ \mathrm{W\,m^{-2}}\ \text{per}\ {}^\circ\mathrm{C\,km^{-1}} \\ \theta_\mathrm{W} &\simeq -8.7\ \mathrm{W\,m^{-2}\,km^{-1}} & D_\beta &\simeq -0.42\ \mathrm{W\,m^{-2}}\ \text{per}\ 1\% \\ \theta_\mathrm{U} &\simeq -4.6\ \mathrm{W\,m^{-2}\,km^{-1}} & \theta_\mathrm{M} &\simeq -0.5\ \mathrm{W\,m^{-2}\,km^{-1}}. \end{aligned} \tag{9}$$

Note that τ is $\partial R/\partial T_\mathrm{S}$; its value agrees with the Planck feedback from AR5 (Eq. (4)).

The data in the OLR datasets isn't good enough for our purposes. The OLR dataset at NOAA from 1974 reads low, and gridding and interpolation lower its resolution too far. The CERES global OLR dataset from 2000 is better, but the period is too short. A major advantage to using the OLR model is that it gives a lot of insight into what is going on.

5.4 The Alterative Model

From the sum-of-warmings model, add the warmings due to ASR and CO_2:

$$\Delta T_\mathrm{S} = \Delta T_\mathrm{S,A} + \Delta T_\mathrm{S,C} = \frac{\lambda_0 \Delta A}{1 - f_{\bar{\alpha}} \lambda_0} + \lambda_\mathrm{C} D_\mathrm{R,2X} \Delta L. \tag{10}$$

Form the alternative model by using the OLR model (Eq. (8)) and energy balance (Eq. (2)) to replace ΔA:

$$\omega \Delta T_\mathrm{S} = \theta_\mathrm{W} \Delta h_\mathrm{W} + \theta_\mathrm{U} \Delta h_\mathrm{U} + g \Delta \Gamma + D_\beta \Delta \beta + \theta_\mathrm{M} \Delta h_\mathrm{M} + \left[\frac{\lambda_\mathrm{C}}{\lambda_0} \left(1 - f_{\bar{\alpha}} \lambda_0\right) - 1 \right] D_\mathrm{R,2X} \Delta L \tag{11}$$

where

$$\omega = \frac{1 - f_{\bar{\alpha}} \lambda_0}{\lambda_0} - \tau \simeq -1.34\ \mathrm{W\,m^{-2}\,{}^\circ C^{-1}}. \tag{12}$$

Hence, for a period between two steady states, the estimate of CO_2 sensitivity is

$$\lambda_\mathrm{C} = \frac{1 - f_{\bar{\alpha}} \lambda_0}{\lambda_0} \left[\frac{\omega \Delta T_\mathrm{S} - \left(\theta_\mathrm{W} \Delta h_\mathrm{W} + \theta_\mathrm{U} \Delta h_\mathrm{U} + g \Delta \Gamma + D_\beta \Delta \beta + \theta_\mathrm{M} \Delta h_\mathrm{M}\right)}{D_\mathrm{R,2X} \Delta L} + 1 \right]. \tag{13}$$

Then the fraction of global warming due to extra CO_2 can be estimated as

$$\mu = \frac{\Delta T_\mathrm{S,C}}{\Delta T_\mathrm{S}} = \frac{\lambda_\mathrm{C} D_\mathrm{R,2X} \Delta L}{\Delta T_\mathrm{S}}, \tag{14}$$

and the ECS as

$$\mathrm{ECS} = \Delta T_\mathrm{S,C}\big|_{\Delta L = 1} = \lambda_\mathrm{C} D_\mathrm{R,2X}. \tag{15}$$

6 The Missing Hotspot

The water vapor emissions layer (WVEL) plays a crucial role in climate. The WVEL is the top band of the water vapor, around one optical depth as seen from space on the wavelengths at which water vapor absorbs and emits. It is, on average, where OLR is typically emitted by water vapor molecules. Upwards emissions by water vapor molecules beneath the WVEL are generally absorbed by water vapor molecules higher up. The WVEL is fairly dynamic, rising and falling as water vapor is moved around the atmosphere, but on average it is in the upper troposphere. If it ascends (that is, its average height Δh_W increases) then it cools and emits less OLR. Its average height is ~8 km, though in the tropics it is ~10 km.

6.1 The Hotspot is Caused by an Ascending WVEL

The "hotspot" is the informal name for a warming of the upper troposphere, in the tropics. The air above the WVEL is dry, but the air below the WVEL is moist and therefore warmer because water vapor is condensing and releasing its latent heat. If the WVEL ascends it creates the hotspot, which is the warming of a volume that was dry and cool when just above the WVEL but which becomes moist and warmer as the WVEL ascends above it.

6.2 When the WVEL Ascends

Surface warming causes more evaporation (70% of the surface is ocean), and the greater volume of water vapor in the atmosphere is presumed to push up the WVEL. This causes the WVEL to cool and emit less OLR, so the other emitters must emit more than otherwise to compensate, including the surface. For the surface to emit more it must warm. This mechanism, called "water vapor amplification" because any surface warming is amplified by the ascent of the WVEL, creates the hotspot.

The main effect of the solar response is to warm the surface, so it also causes the WVEL to ascend. In the conventional models all climate drivers cause the solar response, so surface warming due to any climate driver causes the WVEL to ascend, water vapor amplification, and a hotspot (for GCMs, and to see what the hotspot looks like, see Fig.s 4 and 5 below).

6.3 The WVEL Has Not Ascended in the Last Few Decades

The only instruments with sufficient vertical resolution to measure the change in height of the WVEL over the last few decades are the radiosondes. They show no hotspot. After taking into account tropospheric warming due to surface warming, and due to lapse rate increases caused by that surface warming, the radiosondes show no change or perhaps a slight cooling where the hotspot would be expected. This is not compatible with an ascending WVEL.

Satellites are not suitable because they aggregate information from several vertical kilometers into each data point. Dr Roy Spencer, who pioneered microwave sounding for measuring atmospheric temperatures from satellites, used a different mix of microwave channels to specifically look for the hotspot using the satellite data in May 2015. He concluded: "But I am increasingly convinced that the hotspot really has gone missing. ... I believe the missing hotspot is indirect evidence that upper tropospheric water vapor is not increasing, and so upper tropospheric water vapor (the most important layer for water vapor feedback) is not amplifying warming from increasing CO_2."

The radiosondes also measured specific humidity. Restricting data to the more reliable data in the tropics and mid-latitudes (of at least ~0.5 g/kg) from 1973, there is clearly a drying trend above the 500 hPa altitude level (the WVEL is around 360 hPa). Again, this is not compatible with an ascending WVEL.

6.4 The CO2 Response Causes the WVEL to Descend

Since 1973 the world has seen changes in two main climate influences:

- An increase in solar forcing, mainly due to externally driven albedo. This triggered the solar response, which caused the WVEL to ascend.
- An increase in CO_2 forcing, which caused the CO_2 response. This caused surface warming, which in turn caused the WVEL to ascend. It *also* caused the CO_2-specific feedbacks (which include the rerouting feedback, which lowers the WVEL).

The WVEL moved down in this period. Therefore:

- The CO_2-specific feedbacks caused the WVEL to descend, outweighing the ascent due to the combination of CO_2-induced surface warming and the solar response.
- The CO_2 response caused the WVEL to descend.
- The conventional models (including the GCMs), which predict strong water vapor amplification and a rise in the WVEL in response to *both* increased solar forcing and increased CO_2 forcing, are incorrect.

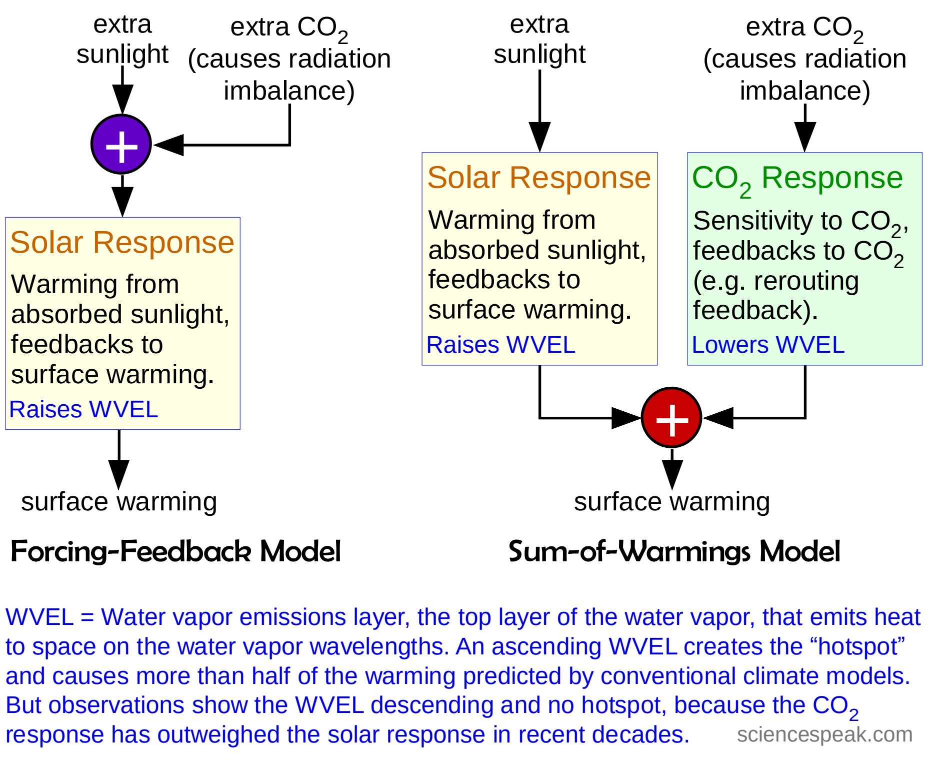

Figure 3: Fixing the architecture by switching from the sum-of-forcings approach of the conventional FFM to a sum-of-warmings finds a much lower sensitivity to CO_2 and resolves the data on water vapor amplification.

7 Effect of Increasing Carbon Dioxide

The climate data is insufficient to form good estimates, but is sufficient to draw interesting conclusions. The change in WVEL height in recent decades was established in the last section as less than or equal to zero. There is cloud height data from 2000 to 2010: the higher resolution MISR data shows a descent of -44 ± 22 m/decade, while the lower resolution

MODIS data shows an ascent of +61 m/decade. There is no suitable empirical data on lapse rates, so we estimated them from the surface warming and the IPCC's lapse rate feedback. There is some general cloud cover data. Various scenarios were evaluated.

We conclude that the basic physics, when the basic climate model's architecture is fixed and modern data applied, shows that:

- The ECS is likely less than 0.25 °C, and most likely less than 0.5 °C.
- The fraction of global warming caused by increasing CO_2 in recent decades is likely less than 20%.
- The CO_2 sensitivity is less than a third of the solar sensitivity.

Given a non-ascending WVEL, it is difficult to construct a scenario consistent with the observed data in which the influence of CO_2 is greater than this. The FFM overestimates surface warming due to increasing CO_2 because it applies the strong solar response instead of the weak CO_2 response to the CO_2 forcing.

8 GCMs have the Same Architectural Errors

The global circulation models (GCMs), the large computer climate models, take many factors into account and are somewhat diverse, but essentially all exhibit the same two architectural flaws as the FFM.

8.1 Omitted Feedback

GCMs can and do include driver-specific feedbacks, such as extra plant growth in response to increased CO_2, but they usually have only a minor effect on the calculated ECS. No GCMs include something like the rerouting feedback that substantially reduces the potency of CO_2, because then they would need drivers other than CO_2 to explain 20th century warming.

8.2 Solar Response Applied to the CO_2 Forcing Feedback

The responses (in °C of surface warming per W m^{-2} of forcing) of different forcings emerge as slightly different in GCMs. The "efficacy" of various forcings can vary by 30% or so. However, the efficacies of the crucial CO_2 and ASR forcings are always similar.

All GCMs apply the water vapor amplification feedback to both CO_2 and ASR, which are both modeled in GCMs as causing a rising WVEL and a hotspot. This is entirely different from the data-driven alternative model, with its CO_2-specific feedbacks that cause the WVEL to fall, and no hotspot.

Here are the outputs from a prototypical GCM, the GISS Climate Model E, showing a similar atmospheric warming pattern to ASR and CO_2 because it applies similar feedbacks to both.

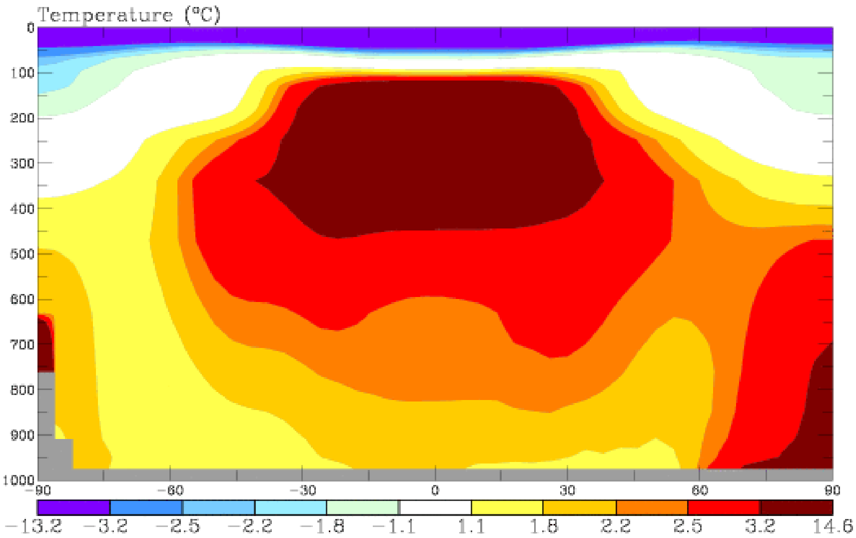

Figure 4: Atmospheric warming when the CO_2 concentration doubles with no change in solar irradiance, as predicted by the GISS Climate Model E. The prominent warming over the tropics at about 10 km (250 hPa, vertical scale) is the hotspot.

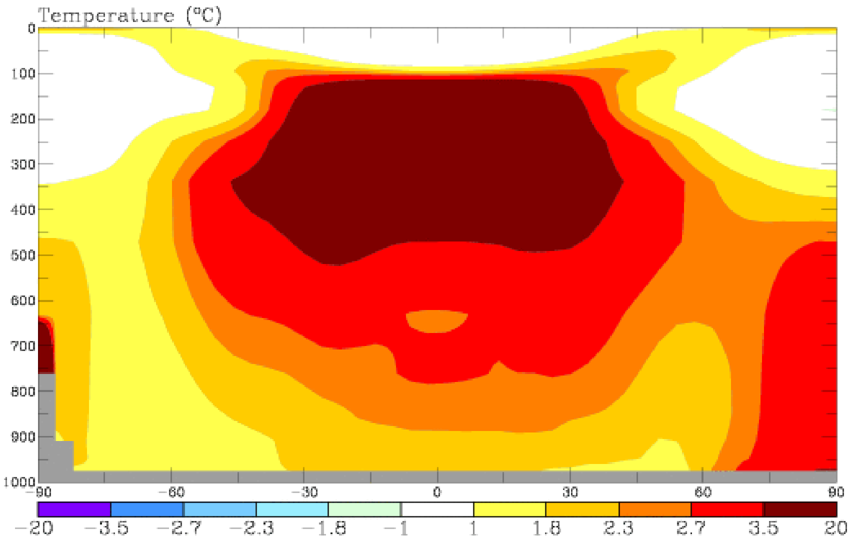

Figure 5: Atmospheric warming when the solar irradiance increases by 2% but CO_2 is held constant, as predicted by the GISS Climate Model E. Very similar to the doubling of CO_2 in Fig. 4—because the same feedbacks are applied.

8.3 Tailored to Give Roughly the Same Sensitivity to CO_2 as the FFM

The GCMs are bottom-up models that try to produce observable macro trends by modelling masses of minor details; many details are not known exactly, so some scaling and tweaking is necessary. However they are indirectly tailored to calculate broadly the same CO_2 sensitivity as the conventional basic model, as follows:

1. The FFM estimates the ECS as ~2.5 °C (Eq. (7)). But this is an overestimate: fixing the faulty architecture shows that the ECS is less than 0.5 °C.
2. An ECS of ~2.5 °C roughly accounts for observed warming since 1910. To believers in the FFM, this confirms that increasing CO_2 explains 20th century warming.
3. So the GCMs use increasing CO_2 as the dominant driver to reproduce 20th century warming. GCMs that do not succeed in this task are not published (see p. 32 here).