

The underestimated role of clouds in global warming: an analysis of climate feedback effects in the AGW-hypothesis

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Summary: *By applying a simple feedback model for the response of the atmosphere to GHG-forcing at TOA, the GCM's CMIP3/5 derived climate feedback values are being discussed in view of a.o. the CERES satellite data about trends in globally averaged surface temperatures and diminishing cloud-cover. It is shown that the trends in cloudiness during the period 1980-2020 are inconsistent with a CO₂-only scenario, unless accepting extremely high ECS values of around 8K/2xCO₂. Taking those trends in cloudiness as extra, independent forcing, results in a value of the climate sensitivity for the change in cloud cover of about 0.09 K/%cc. With that value inserted in the feedback model, it is shown that the often debated "sum of feedbacks" that significantly amplify the effect of increasing CO₂ levels are reduced to almost zero, yielding an ECS of only 1.1 K/2xCO₂ instead of the high values as promoted by the IPCC in their climate projections based upon this AGW-hypothesis.*

The surface temperature of our very complex Earth-climate system, is yet in essence the result of a simple feedback mechanism in which the energy entering the atmosphere as short wavelength (SW) radiation from the Sun and absorbed as heat by the surface, is balanced by the outgoing long wavelength (LW) radiation, related to the black-body emission of the Earth at the top of the atmosphere (TOA) where no other form of energy than radiation can be emitted into space. This energy balance determining the surface temperature T_s can well be described by:

$$C \, dT_s/dt = (1-\alpha) \Phi_0 - \epsilon\sigma T_E^4 \quad (1)$$

in which C is the effective heat-capacity of land + oceans, Φ_0 the average solar power at TOA, α is the albedo of the Earth, T_E is the temperature at TOA, ϵ the emissivity of the Earth at TOA and σ the Planck constant. In thermal equilibrium *i.e.*, for $dT_s/dt = 0$ (in general for $t \rightarrow \infty$) we can calculate the Earth black-body temperature T_E at TOA:

$$\epsilon\sigma T_E^4 = (1-\alpha) \Phi_0 \quad (2)$$

From the average Solar radiation at TOA $\Phi_0 = 340 \text{ W/m}^2$, the average albedo of the Earth system at equilibrium $\alpha = 0.3$, and with the emissivity $\epsilon = 1$ (throughout all calculations) and Planck's constant σ we calculate from eq.1, $T_{E0} = 255 \text{ K}$. Today's average surface temperature is 288 K and applying the relation between that "virtual" temperature T_E at TOA and this "real" surface temperature T_s through $T_E = \beta T_s$ with $\beta = 255/288 = 0.855$, eq.1 transforms into the well-known relation:

$$T_s = \{(1-\alpha) \Phi_0 / (\epsilon\sigma\beta^4)\}^{1/4} \quad (3)$$

This is the response of the surface temperature by the Earth' climate system on the incoming solar radiation *i.e.*, the primary source of energy determining our climate.

If we add a small variation (forcing) F to the right-hand side of eq.1, which could be a perturbation of *either* the incoming SW and/or the outgoing LW radiation at TOA, T_s will ultimately change to a new equilibrium by a small fraction ΔT_s away from T_{s0} according to the gain $(-1/\lambda_{PL})$ of what we can call our Basic Atmospheric Engine (BAE):

$$\Delta T_s = \frac{1}{4} F (T_{s0}/((1 - \alpha)\Phi_0)) = -F/\lambda_{PL} = 0,30 F \quad (4)$$

in which this Planck feedback parameter $\lambda_{PL} = -4(1 - \alpha)\Phi_0/T_{s0} = -3.3 \text{ W/m}^2/\text{K}$. This implies that for every W/m^2 change in the difference between incoming and outgoing radiation and under the condition that all other factors in our climate system remain the same, the surface temperature will change by 0.3 K. Such an imbalance can for instance be created by a change in the concentration of greenhouse gasses (GHG) in particular CO_2 which are kind of “blocking” partially the LW outgoing radiation. This effect with a logarithmic dependence on concentration can be described by a “forcing” at TOA level, characterized by the doubling of the CO_2 concentration $F(2x\text{CO}_2) = 3.6 \text{ W/m}^2$ (see ref. 1 + comment), with the effect of $\Delta T_s = 1.1 \text{ K}$ through eq.4.

Now this ΔT_s can trigger a change in the atmosphere, in particular due to the important role of the ice/water/moisture cycle in the Earth climate system. In the basic assumptions behind the AGW-hypothesis for instance, a higher temperature will lead to less snow and ice, reducing the albedo α , which can be translated into an equivalent forcing F_A . A higher temperature also leads to an extra forcing F_{WV} due to a higher concentration of H_2O molecules in the atmosphere. With H_2O as the most potent greenhouse gas, this water vapor feedback works as an amplifier for the effect of warming by rising CO_2 levels. A higher surface temperature with more moisture in the air must lead to a change

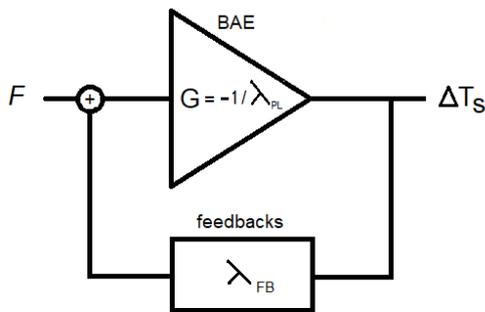


Fig. 1 The crucial feedback loop for calculating the climate response to a forcing F at TOA. The change in surface temperature ΔT_s as output of the Basic Atmospheric Engine (BAE), is fed back to the input through a transfer-mechanism characterized by λ_{FB} . The final temperature increase ΔT_s is given by: $\Delta T_s = G/(1-\lambda_{FB}G) \cdot F$ with $G = -1/\lambda_{PL}$ and $\lambda_{FB} = \sum \lambda_i$ (see text).

$$\Delta T_s = \frac{G}{(1-\lambda_{FB}G)} F$$

in clouds, which are blocking the Sun as well as LW outgoing radiation, and hence, leading to a net cloud forcing F_{CL} . And last but not least, ΔT_s in combination with evaporation and more moisture could affect the vertical temperature gradient governing the upward heat transport, known as the lapse rate which translates into a forcing F_{LR} .

All these “triggered” or secondary forcings are temperature dependent and can/should therefore be regarded as feedbacks from the output of our Basic Atmospheric Engine (BAE) as depicted in fig.1. By treating forcings as perturbations from the equilibrium state of our BAE, we can write the total forcing due to the various feedback mechanisms as $F_{FB} = \lambda \Delta T_s$ in which $\lambda = \sum \lambda_i$ i.e., the sum of all

individual feedback parameters resulting from the forcing related to an increase of the CO₂ concentration. The above introduced feedback parameters λ_i as derived from the various GCM calculations and graphically summarized in fig 2, show a total $\lambda_{FB} = \sum \lambda_i = +1.55 \text{ W/m}^2/\text{K}$ in average for the CMIP5-ensemble.

With the expression for the “closed loop” gain of this amplifier with feedback as already given in fig.1 as $G/(1-\lambda_{FB}G)$ which can be easily verified from basic control theory, we get:

$$\Delta T_s = G/(1-\lambda_{FB}G) \cdot F \quad (5)$$

From which we can now calculate the total effect of a doubling of the CO₂ concentration as:

$$\Delta T_s(2xCO_2) = G/(1-\lambda_{FB}G) \cdot F(2xCO_2) = 0.30 \cdot 3.6 / (1-0.30 \cdot 1.55) = 2.1 \text{ K} \quad (6)$$

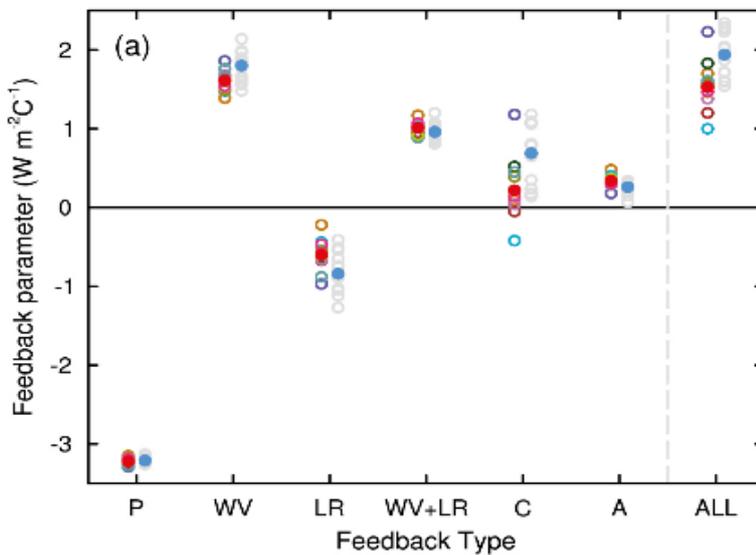
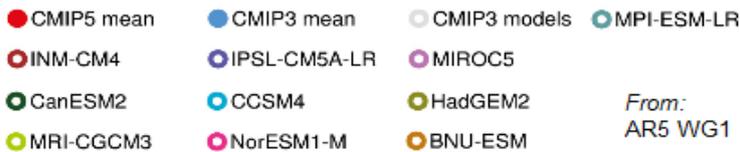


Fig. 2 Graphical summary of all CO₂-forcing-related feedback parameters λ_i as derived from CMIP 3/5: Water Vapor, Lapse Rate, Clouds and Albedo. The Planck feedback parameter is given as reference but is as explained, excluded from the sum $\sum \lambda_i = \text{“ALL”}$

See also ref. 5 for a more extensive picture with additional information.



The climate sensitivity ECS as being the temperature at equilibrium due to a doubling in CO₂ concentration, can be defined by inserting $G = -1/\lambda_{PL}$ in eq.4 as ^{2,3)}:

$$ECR = -F(2xCO_2)/(\lambda_{PL} + \lambda_{FB}) \quad (7)$$

This leads to an Equilibrium Climate Sensitivity ECS = 2.1 K/2xCO₂. Considerably lower than the 3 K/2xCO₂ (or even higher) values promoted by the IPCC, and derived from the same GCM’s as these feedback parameters should be extracted from. However, ECS is very sensitive to the denominator of eq.7 and with λ_{FB} of about 2 W/m²/K and a λ_{PL} of -3.2 W/m²/K as for the CMIP3-ensemble, this simple feedback model reproduces already an ECS fitting well the IPCC range, thus validating this approach.

But anyhow, ECS values from these GCM model calculations are much higher than the ECS of 1.66 K/2xCO₂ in a recent extensive overview/analysis by Lewis *et al* ³⁾ with similar arguments as discussed below to review these 2-4 K/2xCO₂ values as being too high.

Discussion

By rewriting eq.4 in a form as in eq.5:

$$\Delta T_S = G/(1-\lambda_{FB}G). F = -1/(\lambda_{PL} + \lambda_{FB}) \cdot F \quad (8)$$

we can immediately show the problem with the Anthropogenic Global Warming-hypothesis. In spite of large forcings due to volcanic eruptions, meteorite impacts, Milankovitch cycles and you name it, our climate has for millions of years been “controlled” within a tight zone in the order of 12 K (Vostok Ice core data) *i.e.*, $\pm 2\%$ of its nominal equilibrium ($\sim 300\text{K}$) by the Planck feedback parameter. This Planck parameter already represents and includes all atmospheric (feedback) processes as applicable to the anthropogenic CO₂-forcing. Consequently, feedback effects as described above due to a small perturbation in the radiation balance at TOA such as a CO₂-concentration increase, can only result in small perturbations of that Planck parameter.

Doubling in CO₂ generating about 1.5% perturbation of the main forcing at ground level of $0.7 \times 340 \text{ W/m}^2$ Solar radiation, now all of a sudden generates a feedback half the size of that Planck parameter (with opposite sign) to explain less than 1% excursion in basic temperature. This small perturbation has thus, not only the effect of a small temperature change governed by the basic Planck feedback process, but apparently, completely changes the way our strongly buffered climate system works. Without a clear, disruptive reason, the closed-loop amplification of our, for ages already very stable climate system, changes under this 1.5% perturbation by an incredible factor of 2 ($\lambda_{FB} = -0.5 \lambda_{PL}$ vs $\lambda_{FB} = 0$). In the world of control systems this is a unique kind of feedback system with an unimaginable behavior. That this perturbation has some influence on that gain isn't unthinkable, nor that it has even a small feed-forward character, but the absolute magnitude of λ_{FB} can simply not be this large as comes out of GCM calculations.

So, lets first address the various feedback mechanisms involved in GCM calculations on their merits.

Water Vapor and Lapse Rate feedback. In determining the sum of parameters use is made of the fact that water vapor feedback and lapse rate feedback share the same increase of humidity with temperature but with effects of opposite signs. It is argued that their sum at $1 \text{ W/m}^2/\text{K}$ is much more model independent and claimed to be more accurate than the two individual parameters apart. In these parameters it assumed that humidity increases with temperature following an adiabatic model according the Clausius–Clapeyron relation. This is a reasonable approach, but not necessarily true across the entire atmospheric column. At least weather-balloon measurements clearly show discrepancies from calculated vertical water-vapor distributions. Moreover, the LW-absorption by H₂O is already almost fully saturated quite close to the surface, so little change can be expected from a small temperature change. On the other hand, evaporating water to supply this increase in atmospheric water vapor, takes away heat from the surface and thus: it cools. However, without a better physical model than the adiabatic one, it is difficult to argue a sum $\lambda_{WV} + \lambda_{LR}$ much lower than the $1 \text{ W/m}^2/\text{K}$ applied. But later on, we might see some evidence of a much smaller effect and/or a compensating one.

Albedo feedback. Positive feedback is justified from the fact that higher temperatures yield lower sea-ice coverages, thus a lower albedo leading to more sunlight absorbed by the Earth surface. However, the integral effect of sea-ice in the total albedo is already extremely small ^{4,5)} and

moreover, the reflectivity of seawater shows that low-angle reflection as anyhow is “normal” at the poles, is of similar magnitude as the reflective power of ice under small incoming angles. So, the albedo is hardly influenced by small temperature changes and hence, the albedo feedback is either very small if not present at all ^{5,6)}, or even negative ¹⁵⁾. Certainly, when we take the effect of clouds on the albedo also into account ^{4,5,6)}. Increased humidity yields probably more (low) cloud formation which increases the albedo with consequently a negative effect on the albedo feedback. All in all, we cannot other than conclude to a $\lambda_A = 0 \text{ W/m}^2/\text{K}$. But anyhow, it’s no more than just a small correction to λ_{FB} .

Cloud feedback. The real difference making effect in the integral feedback parameter is the value of cloud feedback ⁷⁾ *i.e.*, the warming or cooling of changes in cloudiness (cc) due to temperature changes. For clarity we will refer to this cause-effect relation further on in the discussion as **CC-T**. This in contrast to the feedback where the temperature changes due to a change in cloudiness and from now on, referred to as **T-CC** *i.e.*, the temperature effect due to cloud change. In particular the effect of “*brightening*” as observed on the Northern Hemisphere, and the subject of an earlier study ^{12,13)}.

A CC-T effect with an integrally, positive feedback as used in most GCM calculations is however, difficult to imagine. Intuitively a higher temperature brings more water vapor into the troposphere resulting in more low clouds. Low clouds are supposed to cause cooling *i.e.*, with a clear negative feedback ^{7,9)} at least during day-time. During night-time clouds hinder radiative cooling, but at the same time, average cloudiness at night seems to be lower than during daytime. Integrally, it results most probably into overall negative feedback. The generally accepted solution in GCM’s: high clouds providing positive feedback to compensate and keeping thus the sign of the integral cloud-feedback overall positive. However, satellite data ⁸⁾ show that the high cloud fraction is almost constant at 14% between 1983 and 2010 and so, independent from temperature. Consequently, using them as “compensating” factor for an integrally, positive feedback is a pretty doubtful argument. Moreover, according to the same database ⁸⁾ low cloud coverage diminished over that period from roughly 28 to 24%.

This can only indicate 2 scenarios’:

1. This large cloud change is a CC-T effect due to rising CO₂ levels, which can only happen if we are in a kind of feed-forward “run-away” process towards a hot, fully clear sky climate, or
2. We are seeing the result of the opposite of a CC-T effect, a climate scenario where the temperature increase is (partially) due to a decreasing cloudiness *i.e.*, with T-CC as a major contributor to Global Warming of our climate, independently from rising CO₂ levels.

Why do we conclude to a kind of run-away scenario for the CO₂-only hypothesis?

In fig. 3 & 4 satellite ISCCP and HadCrut/UHA data are plotted ^{8,9)}, in which we drew roughly some trendlines (in view of this first-order analysis a good enough approach). If there is no other cause than rising CO₂ levels for the observed warming, we can derive from these trends a reasonably accurate value for what should be the underlying CC-T-effect. From fig. 3 and 4 ^{8,9)} which are over different time-periods (1983-2008) vs (1980-2020) respectively, we derive:

$$dw/dT_s = - 7 \%/K \quad \text{or} \quad dw/dT_s = - 6 \%/K \quad (7)$$

This difference for the various periods can be due the fact that the effect of *brightening* is less or hardly visibly in the last decade (2010-2020). With an also smaller average rate of change for T_s , the average ratio dw/dT_s is not so much affected.

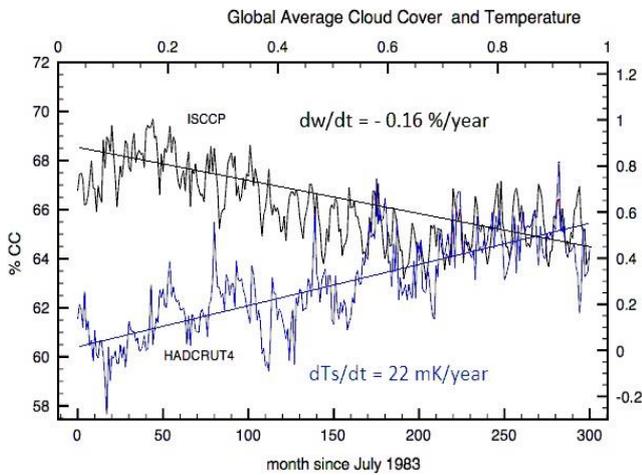


Fig. 3 Trends in cloud coverage and surface temperature, copied from ref. 9 with own, “on-the-eye” drawn trendlines

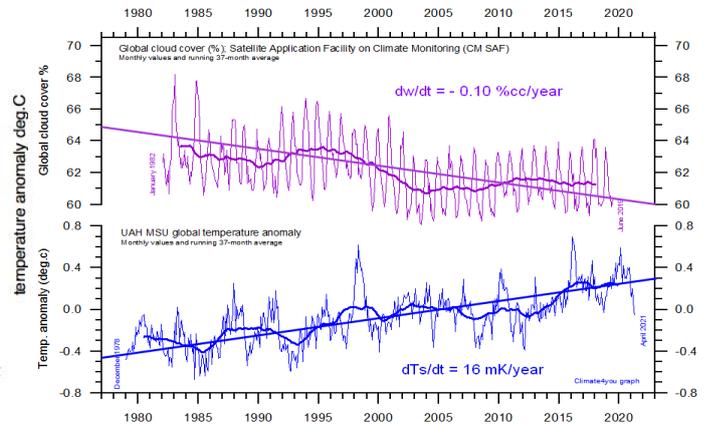


Fig. 4 Trends in cloud coverage and surface temperature, copied from ref. 8 with own, “on-the-eye” drawn trendlines

Since the difference in net-radiation at TOA between *all sky* and *clear sky conditions* is known to be about 18 W/m^2 ¹⁰⁾ at an average cloudiness difference of 66 and 62 % points respectively, it is straight forwardly deduced that this represents a forcing around the *all-sky* situation of at least -0.27 to $-0.29 \text{ W/m}^2/\%cc$. Multiplied with the related values from eq.7, this forcing gives us a best estimate for the cloud feedback that should be used in the CO_2 -cycle of:

$$\lambda_{CL} \approx +1.8 \text{ W/m}^2/\text{K} \quad (8)$$

As expected, this feedback has a positive value as in the GCM’s, but it is much higher than what comes out of the CMIP 3/5 ensembles (see fig. 2). With the arguments given above, not a very plausible outcome. But much more important, this value brings the total temperature related feedback to a value pretty close to $+3.3 \text{ W/m}^2/\text{K}$ *i.e.*, equal to $-\lambda_{PL}$ where the closed-loop amplification $1/(\lambda_{PL} + \lambda_{FB})$ in eq.5 becomes infinite. That implies an enormous amplification for the value of eq.8 of above 2 K/W/m^2 , which is at least 7x larger than the “natural” behavior of the atmosphere on forcings without feedback as in eq.4. And consequently, close to a run-away scenario. And last but not least, the value of eq.8 yields a $\Delta T_s(2x\text{CO}_2)$ of almost 8 K, which is far from any observed reality.

So, the observed reduction in cloudiness simply doesn’t fit the outcomes of GCM’s based upon the generally applied principles of the AGW-hypothesis, nor is it line with surface temperature observations over time.

Hence the conclusion, that a CO_2 -only scenario for global warming is *de facto* falsified by this straight-forward analysis from the satellite CERES-data.

Brightening: a true T-CC effect

As a consequence, we have to consider “alternative scenario #2” as we derived in the paragraph above of an “independent” process of decreasing cloudiness as another cause for global warming. This process of *brightening*, possibly a side-effect of strong reductions in atmospheric pollution since the Club of Rome reports from the '70's of the previous century, triggered major global legislation (a.o. the Montreal Protocol) on the emission of all kinds of pollutants. *Brightening* has been subject of an earlier analysis around this phenomenon¹³⁾. That work is summarized below and the thus derived value for the climate sensitivity of a changing cloud cover is later on used as a reference.

From an analysis of the annual cycle of monthly averaged temperatures that follow the average monthly amount of incoming radiation, be it with a delay of about 1 month, we found an almost perfect linear relationship from which we easily derived an irradiance sensitivity $S = dT_s/dQ$ ^{12,13)} of about 9 K/kJ/cm² for The Netherlands. This accounted for a 1 K temperature increase over the last 4 decades due to a measured 10% increase in incoming solar radiation over that period. Compared to the measured 1.5 K total temperature increase, this would imply that *brightening* is by far the dominant process in this warming. In contrast: the Royal Dutch Metrological Institute (KNMI) published in 2014 a meager 0.2 K estimate for the influence of local *brightening* in their “Climate Scenario's” raising (again) the alarms on anthropogenic warming. The scientific basis for that estimation wasn't revealed, not even in a private communication with KNMI.

It was shown¹³⁾ that this irradiance sensitivity can be transformed into a climate sensitivity to the change in cloudiness (cc). This estimated climate sensitivity for brightening $S^* = -0.11$ K/%cc is somewhat smaller than the value $S_{SAT}^* = dT_s/dt / dw/dt = -0.15$ K/%cc that can be derived from the trends from fig. 4, *i.e.* from the inverse of eq.7. This higher value is however to be expected as those temperature trends used, include possible AGW- and/or other causes of warming as well.

It is good to note, that a change in cloudiness has at least two effects on our climate¹⁴⁾: its “shutter”-effect, modulating not only the incoming – but also the outgoing radiation as well as changing the albedo. In the following analysis, no attempt is being made to separate these two effects, although one might do so by applying a $da/dw = -0.21$ based upon the difference in albedo for a *clear sky* of 0.16 and an *all sky* albedo of 0.30 and an average cloud cover of 68% for the latter situation.

Translation of S* into a forcing F_{CC}

With the reminder above that in the T_s data trend of fig. 3 and 4, the CO₂ related Anthropogenic Warming is included and thus influencing some of the values derived above, we go back to the forcing of these two independent drivers of global warming, in order to assess their independent impact.

Mind that these forcing although different in nature, are individually subject to the same climate feedback parameters as given by eq.5 & 8, and are thus in their size of impact fully comparable.

What we know for sure is that the trend in forcing due to the CO₂ increase during any period of measurement can be derived from the Mauna Loa atmospheric CO₂ data. For the 25 or the 40 years period as used in fig. 3 & 4 respectively, there is not much difference in the rate of forcing at TOA. With $F(2xCO_2) = 3.6$ W/m² and its logarithmic dependence on concentration, we arrive at:

$$dF_{CO_2}/dt = 24 \quad \text{or} \quad 25 \text{ mW/m}^2/\text{year} \quad (9)$$

for the 25- or 40-year period respectively. For the brightening we have to deal with a somewhat less simple picture with $dw/dt = -0.16 \text{ \%/year}$ or -0.10 \%/year , depending on these 25- or 40-years period as used. This leads with the earlier applied TOA data for brightening of $-0.28 \text{ W/m}^2/\text{\%cc}$, to a “cloud change”, or *brightening* related forcing per unit time dF_{CC}/dt of:

$$dF_{CC}/dt = 45 \quad \text{or} \quad 28 \text{ mW/m}^2/\text{year} \quad (10)$$

again, for the 25- or 40-year period respectively.

Although these forcings F_{CO_2} and F_{CC} are of completely different nature, they are within all measurement uncertainties completely comparable. From the values in (10), it is clear that *brightening* causes a substantial forcing, certainly equal but possibly 2x the size of the CO_2 forcing in (9). When added, they show a total forcing of 70 or 52 $\text{mW/m}^2/\text{year}$ averaged over the applied periods, of which *brightening* takes $2/3^{\text{rd}}$ or $1/2$ respectively, and CO_2 the rest. This confirms the about 2:1 ratio claim we concluded earlier for the Dutch situation^{12,13)} through a different approach. The implications of this analysis are clear:

1. The AGW hypothesis is not the prime option for explaining the effect of Global Warming.
2. Without the need to know any feedback parameter, as both forcings are equally subject to them, it can be concluded that whatever value for Global Warming is measured, the ratio between the effect of *brightening* and the effect of Anthropogenic Warming was about 2:1 during the period 1980-2005 and at least 1:1 in average during the last 4 decades.
3. We can without doubt reduce the alarmistic outcomes of GCM models by a factor of 2 to 3.
4. It confirms NASA’s statement about the accuracy of GCMs in relation to cloud effects¹¹⁾.

Climate feedback

With the above in mind, we can now re-assess the feedback loop of the atmospheric response to forcings. Let’s take the sum of eq.9 and eq.10 as integral forcing per year and match them through eq.5 & 8 to the $dT_S/dt = 22 \text{ mK/year}$, or 16 mK/year from the HadCRUT4 data from fig. 3 of fig. 4, respectively. That leads in both cases to the same value for the closed-loop gain of the BAE of fig. 1 (as it should):

$$G/(1-\lambda_{FB} G) = -1/(\lambda_{PL} + \lambda_{FB}) = 0.31 \text{ K/W/m}^2 \quad (11)$$

This is almost equal to the inverse of the Planck feedback, which implies:

The total feedback as introduced to make the AGW-hypothesis accountable for the observed global warming, is (as argued before) almost negligible with $\lambda_{FB} \approx +0.1 \text{ W/m}^2/\text{K}$, and resulting through eq.7 into an ECS = $1.1 \text{ K}/2xCO_2$.

Taking the CMIP’s average for the value of the water-vapor + lapse-rate feedback of $+1.0 \text{ W/m}^2/\text{K}$, **cloud feedback has to be about $-0.9 \text{ W/m}^2/\text{K}$** to make up for $0.1 \text{ W/m}^2/\text{K}$ total feedback from the above analysis. In view of the discussion in that section quite plausible, as an increase in low cloud level generally “cools” and an increase in moisture “warms. Both effects are apparently nature’s “first response” to keep our climate in balance on forcings that would otherwise result into significant higher temperature fluctuations.

So, we don't rule out feedback mechanisms, but they just seem to more or less keep each other in balance. This small overall secondary feedback effect also supports our earlier argument that all those feedback mechanisms that are "necessary" to explain the multiplier effect of rising CO₂ levels on global warming, are already included in the "normal" atmospheric response characterized by the Planck feedback. Those extra, CO₂-induced feedbacks should just be small as they are in fact no more than perturbations of that "overall" Planck feedback that is the ruling parameter of our climate system's basic set-point.

Temperature sensitivity to brightening

Finally, after correcting the slopes of dT/dt from fig. 3 and 4 for the effect of the increase in CO₂ levels (*i.e.* the AGW-effect) and applying the value from eq.11, we can now derive a "true" temperature sensitivity for cloud cover changes from both dT_s/dt and dw/dt as $S_{SAT}^* = -0.09 \text{ K/\%cc}$. This value is very close to the value -0.11 K/\%cc as derived from the annual seasonal cycle¹³⁾. Next to that, Kauppinen and Malmi¹⁷⁾ concluded to this value of -0.11 K/\%cc in a completely different analysis.

In an earlier paper¹³⁾, a reference was made to a paper by Schmidt *et al*¹⁶⁾ who, in their Table 3 "Adjusted Radiative Forcing at the TOA due to the Removal of Each Absorber or Combination", under the heading "Clouds" indicate an (*incoming*) SW-forcing of 47.8 W/m^2 and an (*outgoing*) LW-forcing of -22.4 W/m^2 respectively, as a result of the "removal" of clouds. Assuming a linear relation between the net-forcing and cloudiness at a global average of 68% for the *all-sky* situation, that would imply a cloud-forcing of $0.375 \text{ W/m}^2/\%cc$. Using eq.4 leads to a cloud-sensitivity $S^* = -0.11 \text{ K/\%cc}$, in reasonably good agreement with this $S_{SAT}^* = -0.09 \text{ K/\%cc}$ as derived here. Applying a very simple 1-D/1-layer climate model¹⁴⁾ with clouds as shutters that are completely black for outgoing LW-radiation but semi-transparent for incoming SW-radiation it was shown that the climate sensitivity for changes in cloudiness are of similar magnitude and much larger than assumed in the AGW-hypothesis.

Concluding remarks

High ECS values are the result of large feedbacks. This analysis shows that accepting *brightening* as a major source for warming, those large, unnatural feedbacks aren't needed at all to explain global warming, nor do we need a large ECS. Brightening was certainly a large contributor to global warming during the period 1980-2010, also a period with the steepest temperature rises. The data of the last decade might already indicate that *brightening* is near saturation and just a "one off" effect of the post Club of Rome era of the 20th century, but other effects cannot be excluded. Future might tell.

This analysis and its conclusions don't change the global warming challenge, but the effect of drastic CO₂ reductions is dramatically overestimated and most certainly, not worth the effort.

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