How the CO2 Doubling Temperature is influenced by the Urban Heat Island Effect

And IPCC Lack of Albedo Goals

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Abstract

Global warming has both root causes and amplification feedback effects. The main root cause, believed to be CO2 greenhouse gas, then creates many feedback amplification mechanisms such as loss of ice and snow albedo decrease, increase in atmospheric water vapor and so forth. The strength of the CO2 mechanism is often assessed by its doubling theory. However, such estimates rely on the fact that CO2 is the primary root cause. Numerous authors including this one have found the Urban Heat Island effect to be substantial and should for many reasons be part of our effort to combat global warming problems. Therefore, if one quantifies the UHI effect, it must affect the CO2 doubling theory. In this paper we provide a short overview to illustrate how the CO2 doubling temperature is influenced by the UHI effect. We also assert that having a lack of IPCC albedo goals is highly risky directive.

1. Introduction

The subject of UHI effect having significant contributions to global warming is very important and should remain so. The contention that global warming is only due to CO_2 is very risky as it encourages one to neglect the UHI issues. In actuality, this is perhaps stated mathematically using the doubling temperature estimate since one is given the false sense that the doubling temperature can be estimated without any influence form the UHI effect. Ignoring the UHI effect is unrealistic where many authors have shown their significance. One important paper was by McKitrick and Michaels who in 2007 found that the net warming bias at the global level the UHI effect may explain as much as half the observed land-based warming. This study was criticized (Schmidt 2009) and defended for a period of about 10 years by Mckitrick (see McKitrick Website). Other authors have also found significance (Feddema et al. 2005, Ren et al. 2007, Stone 2009, Yang et al. 2011, and Haung et al. 2015). These studies used temperature station data to make estimates. In a recent study by the author (Feinberg 2020), this contention was supported using a totally different approach using a weighted amplified albedo solar urbanization model, supplemented with footprint studies for amplification factors, and global feedback mechanisms. In this study the author found that UHI with urban coverage could range from 8 to 86% of global warming. The wide range is related to the difficulty of estimating how much land is actually urbanized.

The table below lists the global warming causes and amplification effects. As one can see from the table, UHI effect is a global warming root cause. One would expect that the stronger the influence that the UHI effect plays, the more it should decrease the CO_2 doubling temperature. Therefore, in this paper, we focus on CO_2 doubling theory influence by the UHI effect with a brief overview.

Table 2 Global Warming Cause and Effects

Global Warming Causes →	Population → Expanding Urban Heat Islands (UHI), Roads & Increases in Greenhouse gas
Global Warming Amplification Effects →	Increase in Specific Humidity, Decrease in Relative Humidity, Decrease in land albedo due to cities & roads, Decrease in water type areas from loss of albedo (reflectivity) due to Ice and snow melting
Urban Heat Island Amplification Effects →	UHI solar heating area (building areas), UHI building heat capacities, humidity effects and hydro-hotspots, reduced wind cooling, solar canyons

Loss of Wetlands, increase in impermeable surface, loss of evapotranspiration.

2. Review of the Timeline of CO_2 Doubling Theory

Greenhouse theory and early predictions started as far back as 1856 with CO_2 experiments by Foote, Tyndall in 1859, and what has become very popular, doubling theory by Arrhenius in 1896 [13,14]. Since Arrhenius, doubling temperature estimates based on theory and linked to environmental trends, have decrease as shown in Table 1. The doubling temperature originally 5-6C estimated by Arrhenius shows a range with the last estimates now between 1.5 – 4.5 per the IPCC. Doubling temperature is logarithmic with PPM of CO_2 as shown in Equation 1.

$$13.9^{o}C\ (57.02^{o}F)+2.36^{o}C\ Ln(412/311.8)/Ln2=14.85^{o}C\ (58.73^{o}F),\ 0.95C\ (1.71^{o}F)\ Rise \quad (1)$$

We see that this equation's doubling temperature of $2.36^{o}C$ is very close to the Manabe and Wetherald (1975) estimate in the Table. In general, the doubling temperature value of $2.36^{o}C$ is the temperature increase that one would expect if we doubled CO_2 from 312 to 624ppm. Then we would get another 2.36C increase if we again doubled it to 1248ppm.

Table 1 Key *CO_2* doubling theory history and conflicts

Reference	CO_2 Doubling Temperature	CO_2 Temperature Effect Estimates	Moisture Percent Effect*	UHI Albedo % Forcing Estimates
Arrhenius,1896	5-6^{o}C	5-6^{o}C	-	0
Gillbert Plass,1950's	3.6^{o}C	3.6^{o}C	-	0
Manabe and Wetherald,1975	2.3^{o}C	2.3^{o}C	-	0
IPCC (1^{tst}-5^{th} Assessment 1990-2014, (ECS) equilibrium change	1.5 - 4.5 ^{o}C	1/3	2/3	0
Current Trend, Eq. 1. Based on going from 311.8ppm to 412 PPM from 1951 to Dec 2019, with a *0.95^{o}C (1.71^{o}F)* rise	2.36^{o}C *	1/3 (0.3^{o}C)	2/3 (0.63^{o}C)	0

*Ignoring other GHG

The doubling temperature is based on the fact that CO_2 is the dominate mechanism causing global warming and Equation 1 is written so as to include amplification effect. However, when we include the UHI effect, we would expect the doubling temperature to drop since it is also a root cause, not an amplification effect.

3. CO2 Doubling Theory Estimates with UHI Influence

Equation 1 can be solved for the doubling temperature DT_{CO2} as

$$DT_{CO_2} = \frac{\Delta T_{CO_2+\text{effects}}}{Ln(CO_{2(2019)}/CO_{2(1950)})/Ln2} \quad (2)$$

In this case $\Delta T_{CO2+effect}$=0.95^{o}C, $CO_{2(2019)}$=412ppm, and $CO_{2(1950)}$=311.8ppm, giving

$$DT_{CO_2} = \frac{0.95°C}{Ln(412/311.8)/Ln2} = 2.37°C \quad (3)$$

as expected form Equation 1. Here CO_2 is considered the main cause and this include all amplification effects such as increase in water vapor greenhouse gas (due to the fact that warm air holds more moisture), snow and ice melting etc. Let's assume that CO_2 warming is responsible for 1/3 of global warming and the amplification effects are causing 2/3 (IPCC, 1^{tst}-5^{th} Assessment 1990-2014), then we can write this as

$$DT_{CO_2} = \frac{0.95°C\ \{X_{CO_2} + X_{Feedback}\}}{Ln(412/311.8)/Ln2} \tag{4}$$

where X_{CO2}=1/3, $X_{Feedback}$=2/3. Here X_{other} is an attempt to capture feedback mechanisms. We note that this equation ignores the effects of other greenhouse gases (not including moisture) which are considered as very miner root causes. So in this assessment, they are neglected.

If we have another main root cause, the UHI effect, then the doubling temperature is diminished. Let's say for example that UHI causes f_{UHI} fraction of global warming. For example, if UHI caused 10%, then f_{UHI} =0.1, Incorporating this fractional effect, then the doubling equation becomes

$$DT_{CO_2} = \frac{\Delta T_{CO_2+effects}\ \{(X_{CO_2} + X_{Feedback}(1\text{-}f_{UHI})\text{-}f_{UHI}\}}{Ln(CO_{2(2019)}/CO_{2(1950)})/Ln2} \tag{5}$$

Here we assume that it shares the amplification effect of $X_{Feedback}$, so the CO_2 amplification portion would be diminished by $X_{Feedback}$(1-f). For Example if UHI effect causes 10% of global warming; now $X_{Feedback}$ is reduced to 0.9 $X_{Feedback}$.

Furthermore, the temperature change 0.95^{o}C due to global warming of CO_2 is reduced since a fraction is due to UHI effect. For example if UHI causes 10% of global warming (i.e. 0.95^{o}C) then we must subtract of 10% of 0.95^{o}C=0.095^{o}C. In this example where

X_{CO2}=1/3 and $X_{Feedback}$ =2/3, f=0.1 we have for example

$$DT_{CO_2} = \frac{0.95°C\ \{1/3\text{+}2/3(0.9)\text{-}0.1\}}{Ln(412/311.8)/Ln2} = \frac{\{0.317\text{+}0.57\text{-}0.095\}°C}{Ln(412/311.8)/Ln2} = \frac{0.792°C}{Ln(412/311.8)/Ln2} = 1.96°C \tag{6}$$

Here the global warming CO_2 doubling temperature is diminished form 2.36 to 1.96^{o}C due to the fact that UHI effect is responsible for 10% of global warming (without effects).

To check our results we solbe Eq. 2 for $\Delta T_{CO2+effectz}$, and using DT_{CO2}=1.96, we have

$$\Delta T_{CO_2+effects} = DT_{CO2} Ln(CO_{2(2019)}/CO_{2(1950)})/Ln2 = 1.96^oC\ Ln(412/311.8)/Ln2 = 0.795^oC \tag{8}$$

Then the temperature rise due to the UHI + amplification effect is

$$\Delta T_{UHI+effects} = \Delta T_{gw} f + \Delta T_{gw} X_{Feedback}(1\text{-}f) = 0.95^oC(0.1+0.666(1\text{-}.1) = 0.096^oC + 0.064^oC = 0.16^oC \tag{7}$$

Therefore, the global warming increase is

$$\Delta T_{gw} = \Delta T_{CO_2+effects} + \Delta T_{UHI+effects} = 0.792^oC + 0.16^oC = 0.95^oC \tag{9}$$

as required.

Figure 1 provides an overview of the doubling temperature Equation 5 versus f when X_{CO2}=1/3, $X_{Feedback}$ =2/3 and ΔT_{gw}=0.95^{o}C.

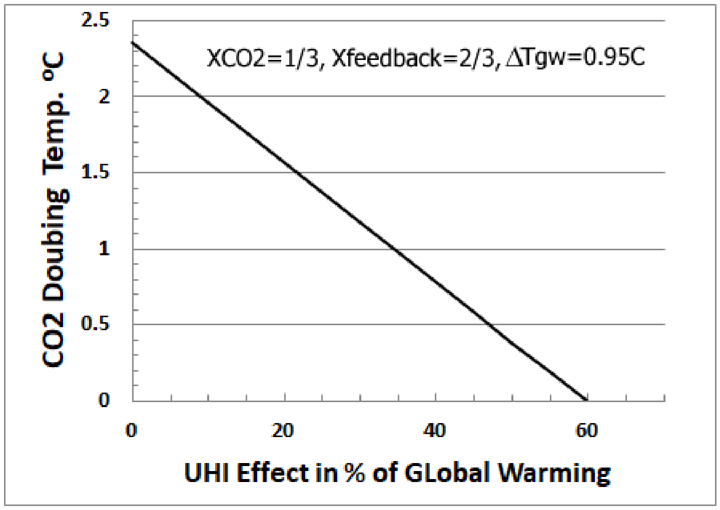

Figure 1 Results of CO_2 doubling temperature with UHI effect (f) increasing influence

Going back to the McKitrick and Michaels 2007 contention that the net warming bias at the global level may explain as much as half the observed land-based warming would indicate that the CO_2 doubling temperature would diminish to 0.39°C according to Equation 5 also indicated on the graph. If that were the case, we see that the CO_2 effect would really not be the main problem with the doubling temperature that reduced. This is perhaps a main reason that the IPCC has been difficult to accept this contention. We see that CO_2 theory has a long history in Table 1. It would be difficult for those who are leading the CO_2 effort to accept this contention. ***Nevertheless, this puts us at risk*** if it turns out the McKitrick and Michaels work is correct along with the many other authors cited in the introduction including this author. We note the references actually go back to 2005.

It is clear that there is certainly cause for alarm why the many authors are being ignored as there is absolutely no real reason for the IPCC to not address this issue through setting albedo goals as they have for CO_2. Each day we take almost no action to try and cool off our cities is valuable wasted time in our fight against global warming while we lose more and more ice and snow. We have of course minimal suggestions of cool roofs, yet there is very little on-going coordinated global effort to make such changes. There is actually no excuse for a better safe than sorry policy. This lack of IPCC albdo goals is highly risky.

4. Summary

We have provided a short review of CO_2 doubling theory and how its doubling temperature changes due to the UHI effect on global warming. Both the magnitude of CO_2 and the UHI effect are obviously hard to estimate on how much influence each has on global warming anomalies. It is important to realize that we most likely have two main root causes of global warming. Both need to be addressed. In our paper (Feinberg 2020) we provided suggestion related to the Urban Heat Island Effect which we would like to include here. As of the time of this paper, the IPCC is still (after 15 years since UHI significance was observed) treating the UHI as only a local effect. We feel this is a serious concern. *We stress that the IPCC is the main governing force and the only agency capable of promoting such albedo changes for cities and roads. Therefore, whether it is just for UHI known health reasons or due to studies similar to ours, we strongly urge the IPCC to set albedo goals and include such goals in their global meetings.*

Therefore our suggestions remain (Feinberg 2020):

- Creating IPCC goals to include the need for albedo enhancements in existing UHIs and roads
- A directive for future albedo design requirements of city and roads
- Recommend an agency like NASA be tasked with finding applicable solutions to cool down UHIs.

- Recommendation for cars to be more reflective. Here although world-wide cars likely do not embody much of the Earth's area, recommending that all new manufactured cars be higher in reflectivity (e.g., silver or white) would help raise awareness of this issue similar to electric cars that help improve CO2 emissions

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