Global Warming Primarily Due to Urban Heat Island with Humidity Forcing
A Feasibility Assessment

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Abstract

In this paper we provide a feasibility study to show that >95% of global warming could be due to Urban Heat Islands (UHI) with Humidity Forcing (HF) from Hydro-HotSpots (HHS). We denote hydro-hotspot as precipitation evaporation and bulk heating from low albedo manmade type roads and city surfaces, including cars and engine hoods. This includes both Highly Evaporating Surfaces (HES) and bulk warm waste Rain Water Management (RWM). Such Humidity Forcing (HF) root cause is then albedo forcing due to the creation of HHS. This leads to the conclusion that changing the albedo of cities and roads could be the main solution to global warming.

1. Introduction

Global warming is commonly illustrated with CO2 correlation to population growth and global warming trends. Similarly, one could argue that city growth is correlated to population growth which in-turn then would also be correlated to global warming if we have feasible mechanisms. Some authors have already shown that as much as a third of global warming is due to UHI [1,2]. This is related to albedo forcing. Along with this one could assert, that city and road growth provides what we term Hydro-HotSpots (HHS) creation. City and road albedo forcing produce UHI high temperatures when in combination with precipitation create Highly Evaporating Surfaces (HES). Such surface as illustrated here are capable of reducing local relative humidity while increasing specific humidity. This combination would then also be correlated to global warming trends. Humidity forcing potential while hard to exactly quantify, is then certainly a possible contributor to global warming. One of the CO2 arguments treats the observed specific humidity increase and relative humidity decrease as due to a warming feedback mechanism from ocean evaporation and ignores the possibility of human humidity forcing [3,4]. Once HF feasibility arguments are made illustrating humidity forcing from UHI from HHS, it diminishes the CO2 argument. We proceed under this conjecture with a simple feasibility assessment with the goal spur strong interest in this area.

1. Highly Evaporation Surface and Rain Water Management Feedback

The effect of UHI and road Hydro-HotSpots (HHS) from Highly Evaporating Surfaces (HES) global warming feedback is illustrated in Figure 1.

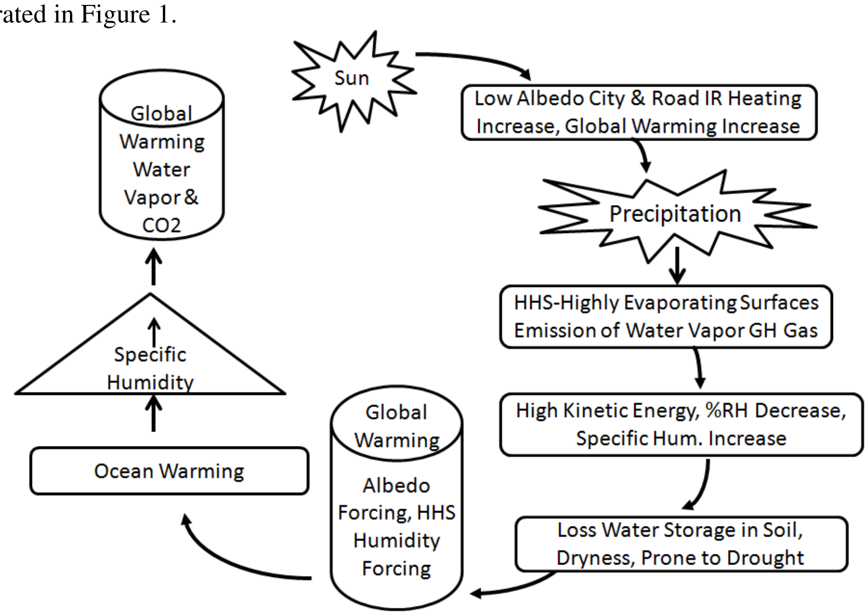

Figure 1 HF-HHS-HES feedback view of contribution to global warming

Figure 1 HES feedback may be summarized as follows:

  - Low albedo forcing increase in cities and roads absorbing sun light and increase in IR creating some global warming effects
  - This is quantified in Section 2.1 in agreement with other authors of about 33%.
- Precipitation occurs, followed by evaporation of HES moisture often with high Kinetic Energy (KE) water molecules from hydro-hotspots (wet hot surfaces)
- HHS temperatures decrease local %RH (see Appendix G and Sec. 2.3) and a higher increase in the specific humidity
- Loss of water storage due to replacement of vegetative areas with cities and roads

- Increase in local dryness and some correlation to the potential for drought (Sec. 4)
- Global warming increase due to albedo forcing and intern higher specific humidity GH gas ocean temperature rise feedback creating more evaporation and higher specific humidity with some CO_2 feedback as well.
- More greenhouse gas in the form of moisture and eventual further warming.
- A large percentage is drained to ocean or nearby rivers that may end up in the ocean (Sec. 4)
- The impermeable city building and roads have replaced vegetative land creating lost area that would have stored cooler water in soil keeping the land moist.
- This increases land dryness and can mean less land evaporation and more ocean rain (Sec. 4)
- The RWM is often warmer from HHS.

2.0 Albedo Forcing - One-Third of Global Warming Feasibility Estimates and Corrective Actions

There have been numerous studies on Urban Heat Island (UHI) effects. We focus only on a few publications that found significance in UHI contribution to global warming. McKitrick and Michaels [5] found that half of global warming trend from 1979 to 2002 is caused by UHI. Research in China [1,2] indicates that UHI effects contributes to climate warming by about 30%. There is an apparent push-back with little effort to date on changing city albedo forcing, as the focus is mainly on CO_2.

A simplistic feasibility model has its strength in

- Supporting estimate from other authors [1,2,5]
- Corrective action assessment using "what if" scenarios for changes to the albedo

Table 1, obtained from Appendix A, illustrates UHI albedo forcing GW feasibility. The simple albedo model supports the contention that cities and roads heat increase can be as much as one-third, in agreement with these few studies [1,2,5]. The table also provides in the last row, a corrective action "what if" scenario for an albedo increase to 0.5.

Table 1 Appendix F Results of GW Temperature Budget Change With City Surface Areas and Albedos

Year	Solar Surface Area of Cities	Albedo Roads	Albedo Cities	Global Albedo	Temperature*
1950	1.20%*	0.04	0.12	29%	0.2°F
2019	2.95% *	0.04	0.12	28.69	0.7°F
2019	2.95% *	0.5	0.5	29.43	-0.5°F

*where Temp is given by: P_{Total}= 1361W/m2 {0.25 x 1-Albedo} $=\sigma T^4$

We note that global albedo changes might be hard to measure from satellites due to cloud coverage, but are undeniable decreasing with increasing cities and roads. City urban areas are not well known and certainly, the solar heating surface area is even more complex to estimate. Although the models in Appendix A on city surface estimate are crude, they demonstrate estimates to further support the cited authors [1,2,5]. From this feasibility we find:

- Actual shift from 1950 may be 0.5°F (0.7-0.2) due to Cities & Road increases, which is 33% responsible for global warming in agreement with the quoted authors [1,2,5].
- A "what if" corrective action results show if we can change city albedos to 0.5 and roads, total shift is 1.3°F ={0.7-(-0.5)}. This almost equates to the observed global warming.

3.0 Percent of Global Warming Due to Greenhouse Gases and Albedo

Under the contention of humidity forcing occurs mainly from cities and roads, we provide feasibility estimates shown in Table 2 of forcing contributions due to Albedo, CO_2, and water vapor increases (ignoring other GH gases) from 1950 to 2019.

Table 2 Calculated Forced Effects Causing Global Warming from 1950 to 2019

Forced Effect	Contributing Change	Temperature Increase	Percentage
Albedo (Cities & Roads)	0.29 to 0.287	0.5°F	33.33%
Water Vapor	403-421 PPM increase	0.937-0.979°F	61.03-65.26%
CO_2	9-27PPM increase	0.021-0.063°F	1.41-4.23%
Totals	430PPM	1.5°F	100%

Table 2 estimates are made as follows:

In Table 1 we concluded the change from 1950 to 2019 due to albedo forcing was 0.5°F.

We next note that the Earth's energy budget is 241.58 Watts/m^2. In 1950 the average temperature was 57^{o}F. This yields 384.93 Watts/m^2. This leaves 143.3Watts/m^2 of power emitted back by GH gases which is 59.34% of the 241.58 Watts/m^2. In 2019 the average temperature is taken as 58.5^{o}F yielding 389 Watts/m^2 which is 147.45 Watts/m^2 above the Earth's energy budget or 61% emitted back by GH gasses. The difference of the emitted back radiation is 4.1 Watts/m^2 and the difference in the percent of the Earth energy budget emitted back by GH gasses is

$$1.7\%=61\%-59.3\% \tag{1}$$

Therefore, this must be the percent of GH gasses required to increase global temperatures 1.5^{o}F. Using the approximate 300 PPM value for CO_2 in 1950 and an average estimate of 25,000 PPM for water vapor in our atmosphere [5, 6], the 1.7% GH gas increase is estimated to be

$$25{,}300\text{PPM x } 1.7\%=430\text{PPM} \tag{2}$$

increase in 2019. In 2019 the estimate increase in CO_2 is 114PPM (currently 414PPM). The typical contribution of blackbody spectrum absorption for CO_2 is 8%-24% leaving 76-92% for water vapor (where we are ignoring other GH gases) [5,6]. It is actually difficult to predict such contribution and we are using values from other authors [5,6]. Using the low 8% value first for CO_2 and the 430 PPM we must have

$$421\text{PPM } (H2O\uparrow) + 114\text{PPMx}8\% \ (CO_2\uparrow)=430\text{PPM} \tag{3}$$

The effect of water vapor and CO_2 vary depending on a clear day or cloudy day with precipitation. Dividing the LHS by 430 PPM yields the fractional GH of 1^{o}F temperature contribution (1.5^{o}F rise from 1950 with 0.5^{o}F due to albedo). The full temperature sum is then

$$0.979^oF \ (H_2O\uparrow) + 0.021^oF \ (CO_2\uparrow) + 0.5^oF \text{ (Albedo)}=1.5^oF \text{ (from 1950 to 2019)} \tag{4}$$

Since CO_2 can vary in it absorption strength, we consider higher values by a factor of 3 in its GH effect [5,6], this upper value yields the estimates to global warming contributions shown in Table 2.

We note the usual argument of CO_2 control in the upper atmosphere is diminished [3,4]. That is, such arguments treat water vapor as a feedback rather than a forcing mechanism. Here, increased warming from albedo forcing feeding humidity forcing from HHS in the presence of precipitation would lessen the CO_2 mechanism conjectured by some climatologist [3,4].

- *In this view, feasibility indicates that the albedo of cities & roads is the main corrective action for global warming.*

4.0 City & Asphalt Hydro-Hotspot Lowering of the Local Relative Humidity Example

If the ambient temperature when it rains is 27^{o}C and 98%RH and the HHS surface temperature is 87^{o}C (black asphalt at 1000Watt/m^2, see Table A1), then the local relative humidity at the hotspot surface is reduced from 98%RH to 5.6%RH. This is shown in Appendix [C]. Such cumulative effect from buildings and streets in a city likely will lower city's equilibrium relative humidity compared to nearby rural areas. This build up is likely over the years related to the ~4.1 Watts/m^2 change seen in global warming. The correlation to lowering relative humidity and global warming is well established [7,8]. One might think that the relative humidity would eventually go back to the original equilibrium state, and it is likely that for the most part it almost does. However, data show that global relative humidity equilibrium is decreasing [7,8] and this must be correlated to the 4.1 Watts/m^2 GW increase. This same energy is then needed to reverse this change.

5.0 Evaporation Rate of Cities Areas, Soil, and Ocean Changes 1950 to Present

Here a simplified formula of the Evaporation Rate of Cities vs that of the Ocean Eo, is used to make comparison between 1950 and 2020. We see that if the evaporation rate in cities is increasing, it would have an increasing contribution to GH moisture gas in our atmosphere by the same rate.

$$\frac{\tau_2}{\tau_1}=\frac{A_2}{A_1}f(T,W,RH,Cv...)=\frac{A_2}{A_1}\overline{f} \tag{5}$$

Where f is some function Temperature T, Wind speed W, Relative Humidity RH, Heat capacity etc. and τ and A are evaporation time and areas respectively. We can further simplify this result as

$$A_2 = A_1\frac{\tau_2}{\tau_1\overline{f}} = A_1\frac{\overline{\tau_2}}{\tau_1} \tag{6}$$

This simplified evaporation rate can be used to conceptualize the effect of city, roads, soil and even ocean. For example, we can compare the changes from 1950 to present day evaporation rate change due to this area effect.

Letting Ao, A_C equal surface areas for Ocean and City Surfaces, the 2019 value is from Table 1 ratio is (Ao/A_C=49%/3%=16.3 versus the 1950 value of Ao/AC=49%/1.2%=40.8 in 1950. This is a factor of 2.5 change in evaporation rate and humidity contribution from cities compared with the oceans feedback mechanism. From Table 2, we see roughly 410 PPM contributing from moisture GH gas has an increase contribution from cities in global warming.

Another simplified expression for the equivalent HHS-HES area from this equation can be written as

$$A_{EfHES} = (\frac{t_{Soil}}{t_{HES}})A_{Soil} = (\frac{t_{Soil}}{t_{HES}})(A_{HES} - A_{HES-\%IG}) \quad (7)$$

Where

A_{EfHES}=Effective HHS-HES area,

A_{Soil}=soil area, this is set equal to an equivalent to A_{HES} area, subtract from

$A_{HES-\%IG}$ any % run off of irrigated water falling on the roads or city surface areas to vegetation areas

t_{Soil} is the evaporation time of the soil

t_{HES} is the evaporation time of the asphalt or city surface after precipitation occurs.

As an example, if it takes a road 2 hours to evaporate a volume of water from a road, while it take soil 48 hours to evaporate the same amount of water in soil, than the effective soil land lost is a factor of 24 times contributing to the evaporation rate and specific humidity. This example is for roads with zero percent irrigation-equivalent area running off water to adjacent land.

The factor $(\frac{t_{Soil}}{t_{HES}}) = \Delta R$ provides an evaporation rate related to the time rate of change. In the above example we see that the rate would be 24 times faster than if roads were not constructed.

6.0 Rain Water Management

Associated with city issues and humidity increase is Rain Water Management (RWM). Impermeable city surface create problems with RWM runoffs. The fact that this bulk water is warm and eventually cools as it evaporates is part of the issue from HHS. Another issue somewhat seemingly unrelated is the loss of wetlands and the increase evaporation rate. Sometimes, rain follows local evapotranspiration. Apart from precipitation, evapotranspiration is the major component in the hydrologic budget. If water is runoff far from the source and there is severe loss of wetland, then the area can be prone to increased dry days and possible draught [15,16]. Many cities dump their runoffs in the ocean and this does not help such situations [17,18].

7.0 HHS-HES and HHS-RWM Reduction Suggested Solutions

- Further studies are required on Humidity Forcing to understand the contribution to GW
- Change Albedo of roads and cities will reducing HHS and the area effect dramatically, i.e. paint roads and building with reflective colors (minimally higher than albedo of 0.5)
- Engineering roads to be more HHS eco-friendly
- Reduce driving speeds during rain to reduce evaporation rates can also reduce KE molecules
- Change to electric cars with HHS - cooler hoods
- Paint all cars metallic or white (high reflective colors)
- Move car engines to the back of the car with as little rain surface area as possible
- Improve HHS-HES irrigation to soil
- Improve vegetation in run off areas by planting millions of trees in HHS-HES areas
- Require negative population growth to reduce increase HHS-HES surfaces
- Adopt Low Impact Development (LID) in city planning and improvements for design approach aiming to mimic naturalized water balances
- Cool rain water runoff with green electricity prior to dumping it in the ocean
- Severe HHS-RWM changes are required to stop runoff into the ocean worldwide

Appendix A Solar City Surface Area Estimates:

One of the main criteria needed for this albedo modeling are estimates of surface areas covered by cities and roads. In 2010, estimates from a GRUMP [9] study and its critics [10] of the study find it is somewhere between 2.7% and 0.85%. We will take a round number of 1% coverage of the Earth in 2010. The growth rate of cities is taken from the U.S. Census of 0.8% per year [11]. We are interested in Global Warming trends from 1950 to 2019. The extrapolation using this growth rate is shown in Column 2 of Table 1. We then need to make some rough estimate that buildings occupied 50 % of the urban land (Column 3). Finally we add a multiplication factor assume each building sides equates to 7 times the bottom surface area in 1950 and as buildings have become taller [12] about 10 times in 2019 (Column 4). The estimates are shown in Table 1 for example the 1950 estimate is 0.62x0.5+0.62x.5x7=2.48 (column 5) and then we take 50% illumination factor (Column 6).

Table A1 Values used to estimate the Solar Surface area in cities

Year	Urban Area Percent	Buildings % Coverage	Surface area & Height factor	Solar surface Area %	50% Illumination
1950	0.62	0.50	7	2.48	1.2
2019	1.10	0.50	10	6.05	3.0

Below we provide a simplified albedo model and illustrates the Earth's energy budget between 1950 and 2019 taking into account these effective solar surface areas.

Appendix B Simplified Weighted Albedo Model 1950 & 2020

Below is a simplified Albedo model to estimate the Earth's total albedo decrease with increase in city and road areas and a decrease in grass lands. Results of the simplified weighted model are exemplified in Table B1 for 1950 with the full estimates provided in Table 1. Equation B1 is the weighted albedo by area, B2 is the weighted albedo with clouds.

$$Earth\ Weighted\ \ Albedo = \sum_i (\%\ Earth\ Area_i\ x\ Surface\ Item\ Albedo_i) \quad \text{(B1)}$$

$$Global\,Weighted\ Albedo = Average\{(Clouds\ Albedo\ x\,\%\ Coverage) + (Earth\ Weighted\ Albedo)\} \quad \text{(B2)}$$

Table B1: Albedo of 0.29 [13], Year=1950

Surface	Enter % of Earth Area	Enter Albedo (0-1)	Weighted Albedo in % Results
Water	71		
Snow	12	0.8	9.60
Ice	10	0.6	6.00
Open Ocean	49	0.06	2.94
Land	29.1		
Roads (0.04)	0.8	0.04	0.03
Urban Cov (0.12)	1.2	0.12	0.14
Forest (0.17)	8.6	0.17	1.46
Grass lands (0.26)	8.6	0.26	2.24
Desert (0.4)	9.9	0.4	3.96
Sum % of Earth Area	100.1		
Weighted Earth			26.37
Clouds (0.47)	67	0.472	31.62
			Global Weighted Albedo in %
Global=Average(Clouds & Weighted Earth) %			29.00
Global=Average(Clouds & Weighted Earth)			0.2900

Appendix C: Example of Hotspot Local Relative Humidity in Cities and Streets

The following equations were used for this estimate in Section 4 [14] regarding the HHS local %RH of 5.6%:

$$HHS_{RH} = RHamb\,\frac{P_{sat}(T_{amb})}{P_{sat}(T_{HHS})} \quad \text{(C1)}$$

Here HHS_{RH} is the hydro-hotspot's local %RH, RH_{amb} is the ambient %RH, and P_{sat} is in KiloPascals defined as

$$P_{sat}(T) = e^{(a+\frac{b}{T}+\frac{c}{T^2}+\frac{d}{T^3})} \quad \text{(C2)}$$

Where a=16.033225, b=-3515.138, c=-290850.583, d=5097236.05, and T=Temperature in ^{o}K. Psat can also be obtained from standard tables.

Biography: Alec Feinberg is the founder of DfRSoft. He has a Ph.D. in Physics and is the principal author of the books, Design for Reliability and Thermodynamic Degradation Science: Physics of Failure, Accelerated Testing, Fatigue, and Reliability Applications. Alec has presented numerous technical papers and won the 2003 RAMS best tutorial award for the topic, “Thermodynamic Reliability Engineering.”

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