Global Warming Due to Albedo & Humidity Hydro-Hotspots Forcing

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Abstract

Understanding root causes is always needed to find proper solutions. ***In*** *climate change, we must ask, what has historically changed? Besides CO_2, we have a change in the specific and relative humidity, slight decrease in land albedo, and yearly growth of Hydro-HotSpots (HHS). We denote hydro-hotspot as water evaporation and bulk heating from low albedo manmade type roads and cities surfaces (often called urban heat islands), including cars and engine hoods. This includes both Highly Evaporating Surfaces (HES) and bulk warm waste Rain Water Management (RWM) where billions of gallons of water is into rivers and the ocean each year causing numerous concerns. This is Humidity Forcing (HF) related to albedo forcing and the creation of HHS. Most significant is land albedo forcing. Modeling provided are in agreement with other authors that albedo forcing due to cities and roads are a major effect on global warming. This also feeds most of the HHS.*

We show in this article that such surfaces, while seemingly covering only about 1% of the Earth, can have very large effective solar and evaporation areas many times the size of the HES and RWM area itself compared with higher albedo absorbing vegetative areas that also include transpiration. This is significant since water vapor is the most potent GreenHouse (GH) gas. City surfaces can prove to be enormous when tall buildings are considered. In addition, hydro-hotspots will decrease relative humidity while increasing specific humidity. We are able to estimate the large percentage of global warming contribution due to albedo and humidity HHS forcing compared to CO_2 increase. This leads to the conclusion that changing the albedo of cities and roads is the main solution to global warming.

1. Introduction - Highly Evaporation Surface and Rain Water Management Feedback

In this paper we look at the effect of Hydro-HotSpots (HHS) from Highly Evaporating Surfaces (HES) feedback (Figure 1A) and Rain Water Management feedback (Figure 1B) contributions to global warming.

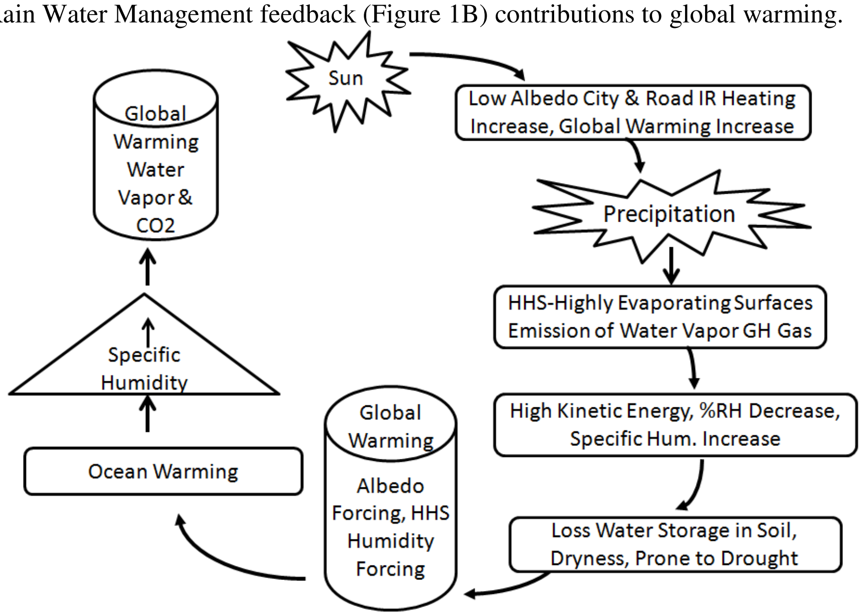

Figure 1A HF-HHS-HES feedback view of contribution to global warming

Figure 1A 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.

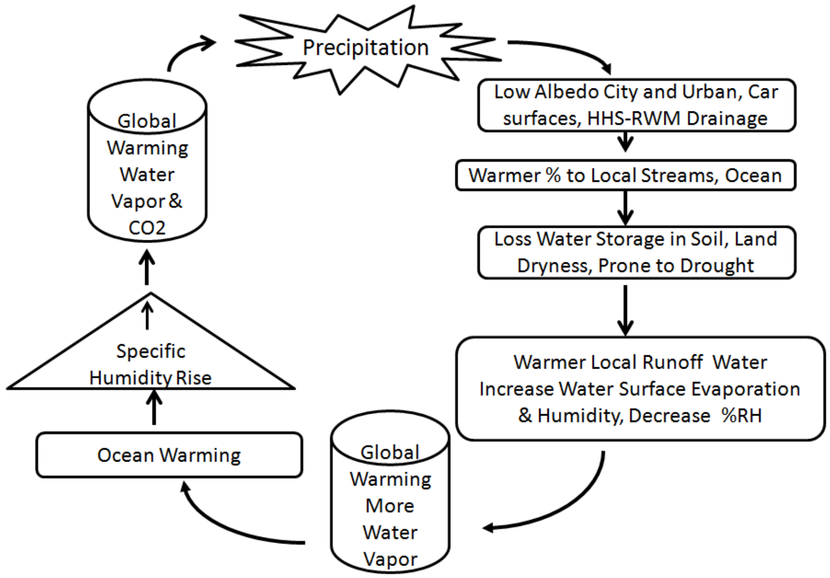

Figure 1B HHS Rain Water Management (RWM) feedback in Climate Change

Figure 1B HHS-RWM feedback may be summarized as follows:

- Precipitation is collected off of HHS buildings, streets and hot cars
- 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 than streams and ocean water can contribute to local surface water temperature increase. Possibly warmer environment may runoff more water to the ocean due to population trends. See studies (Sec. 4).
- This above Humidity Forcing (HF) effects would contribute to a global warming feedback cycle and rising specific humidity and drought prone areas due to runoff distances.

In Section 2 we provide Models for Albedo and Humidity forcing and quantify forcing effects due to albedo and GH gases, in Section 3, we overview relevant data, in Section 4 we discuss details of HHS-RWM, including how lost wetland water storage is correlated to dry days and possible drought, in Section 5 we discuss reasons why CO2 is not a main solution to Global Warming (GW) problems and in Section 6 we provide a brief summary, conclusion and suggestions.

2.0 Albedo & Humidity Hydro-Hotspots Forcing Models

Here we provide albedo and humidity forcing modeling to illustrate and strengthen the concept shown primarily in Figure 1A.

2.1 Albedo City Forcing Modeling to Illustrate Literature Agreement - Global Warming Partial Solution

When we ask what has change since 1950, we need to consider an albedo forcing due to roads and city surfaces. As we build cities, we increase the effective solar area of the Earth. 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 [1] found that half of global warming trend from 1979 to 2002 is caused by UHI. Research in China [2,3] indicates that UHI effects contributes to climate warming by about 30%. There is an apparent push-back as little attention to date is on changing city albedo's forcing as a major solution to global warming, as the focus is mainly on CO_2. Here we can show with some basic albedo modeling that cities and roads are large contributor to global warming, in agreement with these few studies [1-3].

The main criteria needed for this modeling are estimates of the surface area covered by cities and roads and an effective albedo. GRUMP [4] found about 0.9% coverage of the Earth is by urban areas. This study was done in 2010 and was somewhat disputed. Nevertheless we are using it as a starting value with an increase update estimate of 1.2% for the 2019 first approximation. Along with this estimate, we need some sort of adjustment for solar surface area needed to account for city building sides.

This increase is hard to quantify and certainly merits studies. As a rough estimate for this model, we assume each building sides equates to 10x the bottom surface area due to having 4 sides and their height. Assume now that buildings take up 45% of a cities area. Using the 1.2% of the Earth surface are cities estimate, we then have 1.2%x55%+1.2%x45%x10=6% of the Earth's surface could show an increased from 1.2%. If 50% of this is illuminated on building sides, this is 3% in solar heating area compared to 1.2% estimate (a factor of 2.5 increases in urban solar area). In 1950 we used 0.48% for the city surface area yielding, (0.48%*0.55+.48%*0.45*10)x50%=1.2%. Here we have probably inflated the value in 1950 to be conservative as this actually diminishes the effect from 1950 to 2019 for city surface area yielding only a 2.5 factor increase.

In Appendix F we also provide a "what if" we could change the 2019 albedo of roads and cities to 0.5. Table 1 summarizes the findings in Appendix F

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

Year	Surface Area of Cities	Albedo Roads	Albedo Cities	Global Albedo	Temperature Budget
1950	1.20%*	0.04	0.12	29%	0.2^{o}F
2019	2.95% *	0.04	0.12	28.69	0.7^{o}F
2019	2.95% *	0.5	0.5	29.43	-0.5^{o}F

*City surface area increase due to building sides. Estimate (also see Sec. 3).

Although the models in Appendix F and on city surface estimate are crude, they demonstrate the need for feasibility studies further support to the cited authors [1-3]. From the crude modeling we have shown:

- Actual shift from 1950 may be 0.5^{o}F (0.7-0.2) due to Cities & Road increases, which is 33% responsible for global warming in agreement with the quoted authors [1-3].
- A "what if" results that shows if we changed the albedo to 0.5 of cities and roads, total shift is 1.3^{o}F {0.7-(-0.5). This almost solves global warming problem
- Due to improvements of specific humidity (see next section), it should actually solve most of the problem.

We see that with the HHS-HES issues and this albedo change, is likely nontrivial to requiring cities worldwide to be more reflective. With the infrared technology today, it is easy to pinpoint urban island buildings that are problematic and find possible solutions.

2.2 Percent of Global Warming Due to Greenhouse Gases and Albedo

In this section we provide basic calculations supporting the conclusions in Table 2 for 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	Temperature Increase	Percentage
Water Vapor	0.937-0.979^{o}F	61.03-65.26%
Albedo (Cities & Roads)	0.5^{o}F	33.33%
CO_2	0.021-0.063^{o}F	1.41-4.23%
Totals	1.5^{o}F	100%

In Table 1 we concluded the change from 1950 to 2019 due to albedo forcing was 0.5^{o}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

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

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°F temperature contribution. The full temperature sum is then

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

Since CO_2 can vary, here taken by a factor of 3 in its GH effect [5,6], this variation 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 (see Sec. 5 and references therein). That is, such argument treat water vapor as a feedback rather than a forcing mechanism (Sec 5). Here, increased warming from albedo forcing an in-turn humidity forcing now allows a similar proportional argument, since higher altitude availability of water vapor can increase with warming. Then the CO_2 effect is likely diminished in this view.

- *This leads to the conclusion that changing the albedo of cities & roads is the main solution to global warming.*

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

If the ambient temperature when it rains is 27°C and 98%RH and the HHS surface temperature is 87°C (black asphalt, 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 G. 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 and some data are provided in the next section. 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, we have seemingly fallen away from that global relative humidity equilibrium (see next Section) and would need this same amount of energy of 4.1 Watts/m^2 to reverse the change.

2.4 Basic Global Warming Humidity Relationships Over Land

Numerous authors have illustrated that global warming is dominated by moisture content in the atmosphere [see Byrne et. al. and references therein, 7]. This can be expressed with relationships of specific humidity h, and relative humidity r. For example, Byrne et al. [7] observe GW_L temperature over land increase of 0.17±0.04°K per decade, a specific humidity (h_L) increase over land of (0.08±0.04g·kg^{-1}per decade), and a relative humidity (r_L) linear decrease trend of −0.22±0.20% per decade. Using these observations, we can formulate some functional relationships to understand global warming change with specific humidity in the atmosphere as

$$\frac{dGW_L}{dh_L} = \frac{dGW_L}{dt}\frac{dt_2}{dh_L} = \frac{0.17}{0.08} = 2.13 \tag{6}$$

As well this provides an opportunity to write the time rate of change of Global warming with the time rate of change in specific humidity increase in the atmosphere

$$\frac{dGW_L}{dt} = 2.13\frac{dh_L}{dt} \tag{7}$$

Similar to (6) we can write the change in global warming over land with the change in relative humidity r over land

$$\frac{dGW_L}{dr_L} = \frac{dGW_L}{dt}\frac{dt_2}{dr_L} = -\frac{0.17}{0.22} = -0.77 \tag{8}$$

This also provides an opportunity to write the time rate of change of global warming with the time rate of change in relative humidity decrease in the atmosphere as

$$\frac{dGW_L}{dt} = -0.77\frac{dr_L}{dt} \tag{9}$$

From our conjecture of the sources of these changes in the atmosphere related to greenhouse gasses and our new assertion related to HHS, then the change in r_L and h_L in the atmosphere is some function of $CO_2(T_{rad},O_f)$, HHS(Albedo,p) and other GreenHouse Gasses ($GHG_{other}(T_{rad})$), that is

$$\frac{dr_L}{dt} \sim \frac{dh_L}{dt} \sim \frac{df\{CO_2(T_{rad},Oc), HHS(Albedo,p), GHG_{other}(T_{rad})\}}{dt} \tag{10}$$

Here p is the precipitation, T_{rad} is the increase in temperature due to re-radiation of CO_2 IR back to Earth, O_r is the ocean feedback that creates an increase GH moisture gas evaporation due to rising temperature of the CO_2 re-radiation. We can summarize these general relationships on global warming change over time having the form

$$\frac{dGW_L}{dt} = -k_r \frac{dr_L}{dt} = k_h \frac{dh_L}{dt} \sim \frac{df\{CO_2(T_{rad}, Oc), HHS(Albedo, p), GHG_{other}(T_{rad})\}}{dt} \tag{11}$$

where each k is a constant that varies with measurement accuracy. It is important to note that CO_2 in general goes into the atmosphere primarily from land. Therefore, for this feedback to occur, the CO_2 must spread into the atmosphere across the ocean sky area, and then eventually, the ocean gets warmer, which in turn creates ocean evaporation. This is in contrast to the more direct effect of HHS which occurs only over land. On the other hand, we note that HHS is also a function of precipitation. HHS requires a combination of sun absorption and timely precipitation which reduces its influence.

2.5 HHS-HES Effective Area of Evaporation Change from Soil

In addition to the increase in solar heating area in cities, one must understand the HHS-HES areas are increasing with growth of cities and roads. This increase moisture evaporation is tied to the increase area and the effective evaporation change since 1950 which occurs due to replacing soil with impermeable surfaces.

A simplified expression for the equivalent HHS-HES area found in Appendices A, B, and C roughly given by

$$A_{EfHES} = (\frac{t_{Soil}}{t_{HES}})A_{Soil} = (\frac{t_{Soil}}{t_{HES}})(A_{HES} - A_{HES-\%IG}) \tag{5}$$

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. In the appendix this rate is shown as a function of

- $\Delta R\{(Exp(-(E_a/k_B\ T))$, average soil vs asphalt specific heat Cv, dCv/dt, dm/dt, average Δalbedo, soil diffusion rate, evapotranspiration, wind speed}
- HHS-HES from cars**:** This effect may be significant as car surface area temperatures vary with color and hood temperatures. As well, unlike cities that cool-off at night, hood temperature in the rain still create HHS'. This also causes hot runoffs. As well there are likely other combustive areas. (see solutions).

3. HHS-HES Supporting Related Data Trends

The following data and analysis are summarized that supports HHS-HES feedback:

- **HHS-HES Areas on Average are Hotter:** When evaporation occurs from cities and roads, the albedo is on average lower by comparison to vegetative areas that are replaced. Often evaporation is then from hotter surfaces, molecules then have higher kinetic energy, this expands air and decrease relative humidity (see Appendix G). Even when surfaces are not hotter, the evaporation rate increase is associated with higher entropy, higher specific humidity and lower relative humidity. This is discussed in Section 4.

- **HHS-HES area effect**: A simplified analysis is presented in Section 2.3 illustrating when all things are equal, the area lost from soil water storage due to roads and cities, for example is given primarily by the differences in evaporation times between the would be vegetative area and the city or road replacement area. The example is given there that if it takes a road 2 hours to evaporate a volume of water from a road, while it takes soil 48 hours to evaporate the same amount of water in soil, then the effective soil land lost is a factor of 24 times, contributing to the HHS evaporation rate, specific humidity and global warming emitted moisture greenhouse gas. Although we have not formulated this rate related to transpiration, the rate should still apply.

- **HHS-HES city area effects**: As we build cities, we increase the effective solar area of the Earth. The increase is hard to estimate. A rough estimate was provided in Section 2.1.

- **Specific Humidity Rising:** Figure 2A shows the increase in specific humidity not just to warming oceans but also over land mass. Overall, water vapor in the surface atmosphere has increased over land and ocean since the 1970s (specific humidity is rising) [8], while the atmosphere over land is becoming less saturated (relative humidity is dropping) [8].

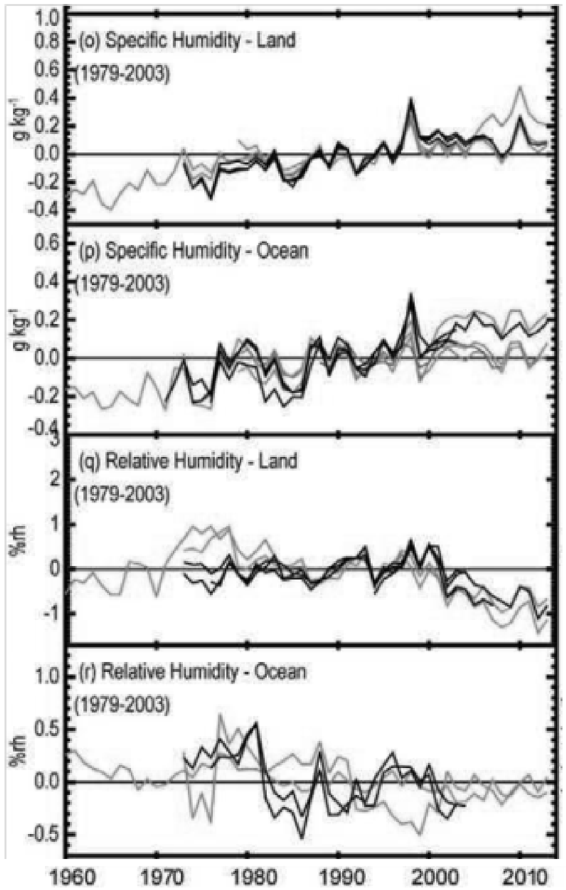

Figure 2A Top two figures shows the specific humidity over land and water both increase while the third figure showing the relative humidity decreasing trend primarily over land while the ocean is more stable but likely harder to measure [8].

- **Precipitation:** Figure 2B illustrates that precipitation has remained constant [8] even though the specific humidity has increased. However in Fig. 7 and 8 we see that in later years it is actually increasing.

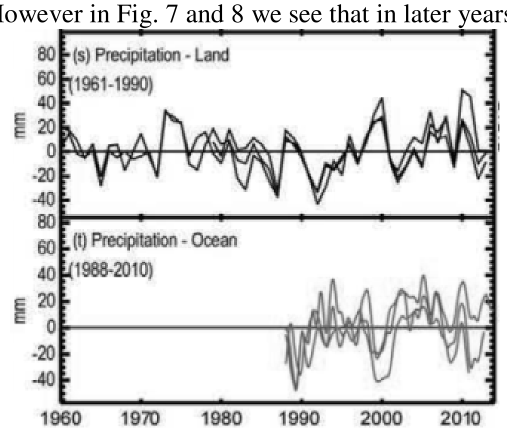

Figure 2B A fairly constant precipitation rate in view of the fact that the specific humidity is increasing [8]. In later years Fig. 7, shows precipitation eventually increasing.

- **Soil Moisture:** Figure 3 shows a decrease in soil moisture [8] likely suggesting a correlation to global warming. This increase in dryness is made worse from HES areas in cities and roads increasing over time.

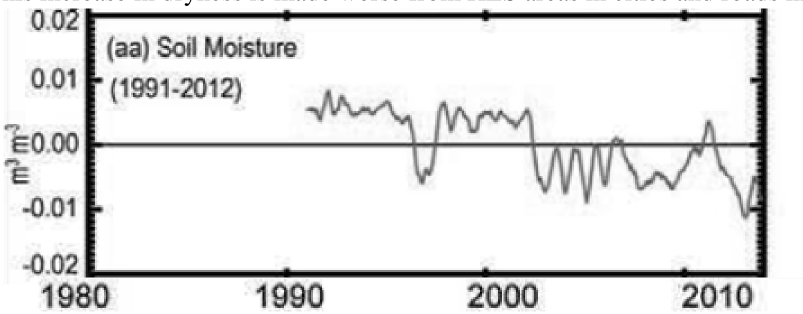

Figure 3 Loss of soil moisture likely due to global warming over land [8]

- **Albedo decline:** In Figure 4, a decline in land albedo [8] is found. One would expect this decrease over land due to the increase in roads and city areas having a much lower albedo value than natural vegetative areas. Global albedo loss has been blamed on glacier loss but here it is illustrated just for land.

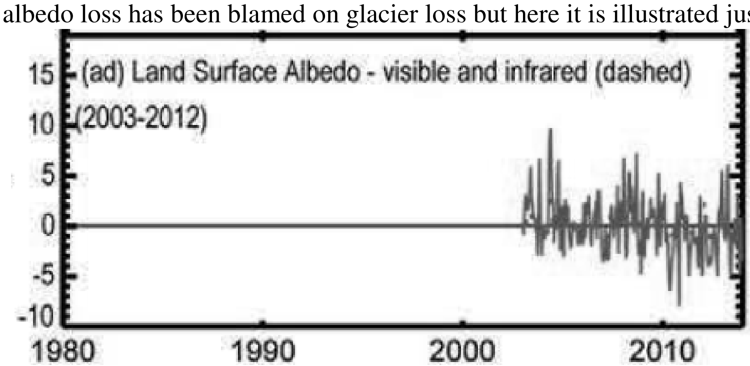

Figure 4 Loss of albedo over land likely due to increase in cities and highways [8]

- **Increase in Asphalt use:** Figures 5 and 6 show an increase in asphalt use (2009-2012) and increase in highway miles (1923-2009), respectively [9,10]. Although the data is limited on asphalt and highway growth, the trend is clear. Climatologists correlate the rising CO_2 greenhouse gases to global warming. Here one could just as well correlate the rising use of asphalt to global warming via contributions from the HES effect and emission of greenhouse water vapor gas**.**

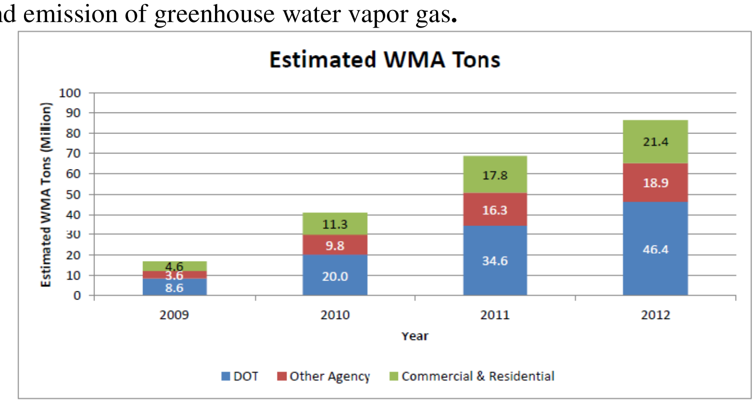

Figure 5 Growth of Warm Mixed Asphalt Usage per year (2009-2012) in USA [9]

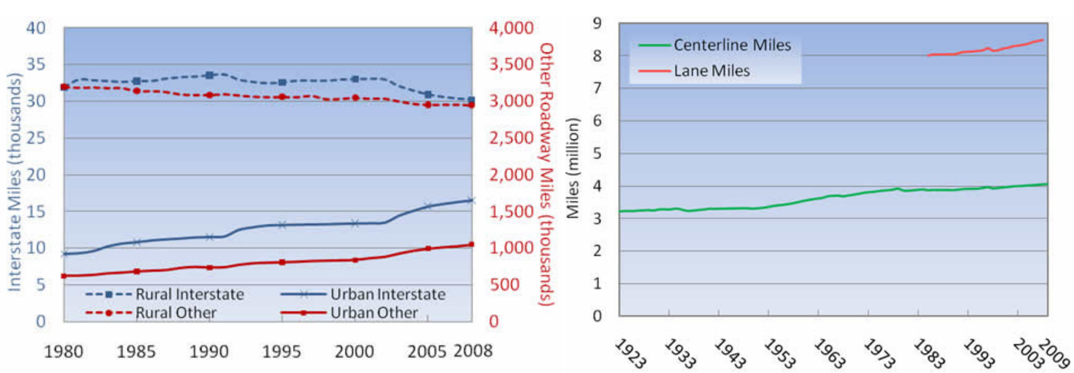

Figure 6 Interstate Miles versus yearly increase in US [10]

- **Specific Humidity Trends and Correlation to Global Warming:** Figure 7 shows specific humidity trends and Figure 8 illustrates the correlation through 2017 from various sources [8]. Here the author does not differentiate between specific humidity and precipitation.

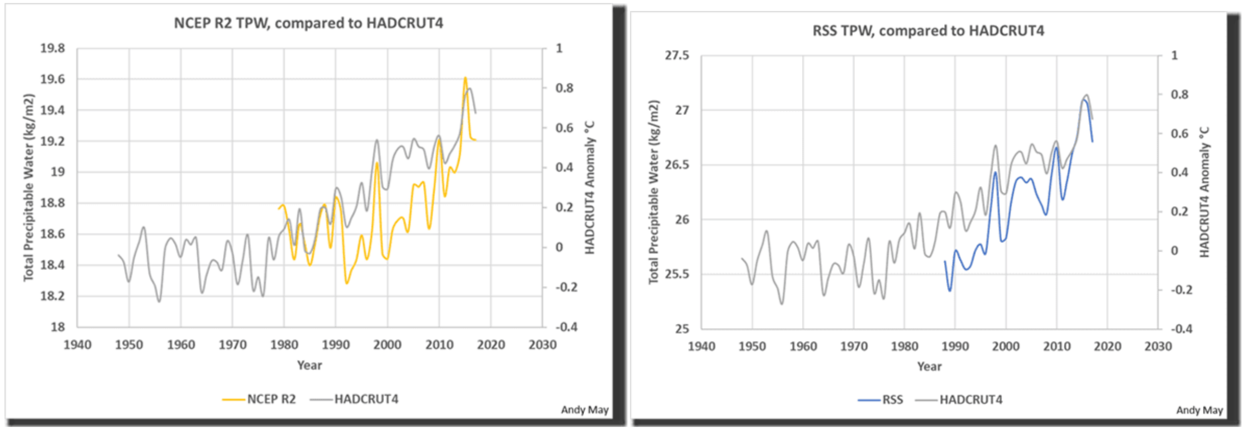

Figure 7 Specific humidity and global warming trends from two different agencies [11]. Here the author does not differentiate between specific humidity and atmospheric precipitation.

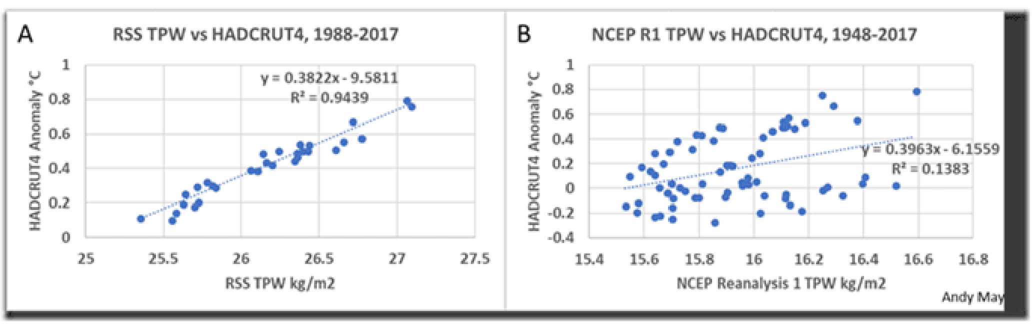

Figure 8 Correlation of specific humidity - Total Precipitation Water (TPW) for different data with global warming [11]. Here the author does not differentiate between specific humidity and atm. precipitation.

The primary effect that we are looking at with respect to data is a possible contribution to the evaporation rate and its effect on the rising specific humidity in the troposphere (lower 10 miles of atmosphere). Other related effects are likely dry conditions that are a necessary but not sufficient condition for drought. Hot roads and city walls also expand air and not only drive up specific humidity during precipitation but lower %RH (Appendix G). One other critical effect that is hard to calculate is loss of plant water storage and transpiration. When impermeable surfaces replace vegetation, the rate of evaporation is exceedingly high compared to transpiration which is said to account for 10% of all evaporation [12]. Climate change is then hard to predict. Lost wet lands can lead to dry condition with less increase in specific humidity.

4. Data on Rain Water Management (RWM), Drought, Global Warming Trends

Rainwater management may be an important factor. It can also impact where it rains! Rain follows local evapotranspiration. Apart from precipitation, evapotranspiration is the major component in the hydrologic budget. If ocean precipitation increases, then land precipitation can decrease.

When it rains in a city, much of the land in urban areas is covered by pavement or asphalt. Because rain can't soak into the soil underneath, these covered areas are impermeable surfaces. As the amount of impermeable surface increases with urbanization, so too does the amount of runoff. As an example, in urban cities 30% is often estimated for evapotranspiration, 10% shallow soil infiltration, 5% deep soil infiltration, and RWM takes 55% into runoff.

- The New York Environment Report, in 2014 reported [13], "Every year, old sewers flooded by storm water release more than 27 billion gallons of untreated sewage into the New York Harbor alone."

- Fry et al [14] reported that in February of 2019 California estimated that 18 trillion gallons of rain in February alone had most of the water going to the Pacific Ocean. The article goes on to point out the LA dept. of water captured 22 billion gallons of water during recent storm.

As roads and cities have increased, so too has the albedo decreased, in cities like LA, HHS-RWM runoff can have major impact on local ocean temperature increase and evaporation from its surface. Land can also become dryer as there is less water storage in wetlands as shown in Figure 1B. As the water storage is shifted from the land to the ocean, local precipitation could hypothetically be affected. The precipitation could change to more over the ocean and less over the land. This could make the local area more prone to drought and higher average temperatures. When it does rain over drought areas, the runoff is warmer and will eventually create more evaporation either during the runoff or when dumped into local ocean areas which could affect moisture greenhouse gas. This could create a feedback cycle of higher temperature on land and again warmer runoff see Fig. 1B.

Here we cite examples on some studies that found correlations to wetland and rain. Such studies can depend obviously on climate of the area. However, these examples show the importance in losing wet land (water storage).

Cao et. al. [15] did a study on wet land reduction in China and correlation to drought with the following conclusion

- "The wetland distributions and areas of the five provinces of southwestern China in the 1970s, 1990, 2000 and 2008 show that the total reduction of wetland area was 3553.21 km^2 in the five provinces of southwestern China from 1970 to 2008, accounting for about 17% of the ground area, and thus the average annual reduction area is about 88.83 km^2. The reduction rate was comparatively fast from 2000 to 2008 with an average annual reduction of 329.31 km^2. The changes to the wetland area show a negative correlation with temperature (i.e. wetland decrease, increase in temperature), and a positive correlation with precipitation (i.e. wetland decrease, precipitation decrease)." [15]

Hirshi et al. [16] did the following study

- "We analyzed observational indices based on measurements at 275 meteorological stations in central and southeastern Europe, and on publicly available gridded observations. We find a relationship between soil-moisture deficit, as expressed by the standardized precipitation index, and summer hot extremes in southeastern Europe. This relationship is stronger for the high end of the distribution of temperature extremes. We compare our results with simulations of current climate models and find that the models correctly represent the soil-moisture impacts on temperature extremes in southeastern Europe, but overestimate them in central Europe."

Below is the graph from their study [16]. It shows a negative linear relationship between wet land decrease and dry day increase

$$\%HD = -k\ WL(\text{Water Runoff and/or Loss of Wet Land}) + b \tag{12}$$

where k is the slope related to the dryness. Here we have taken some liberties and generalized it to include water runoff.

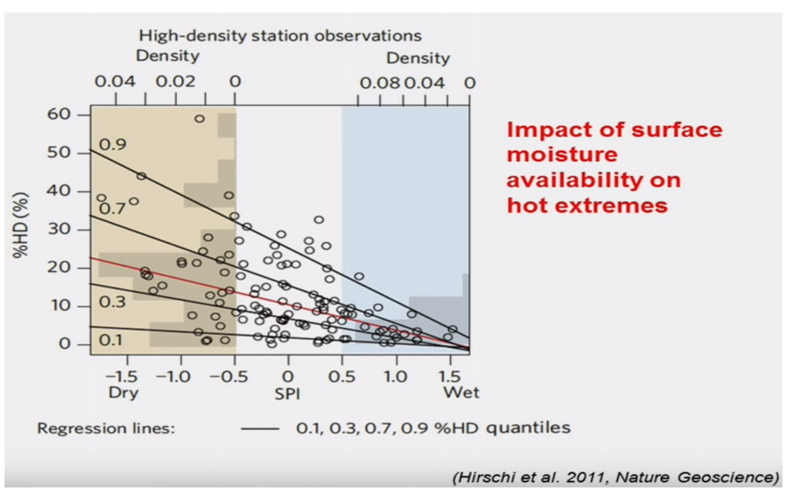

Figure 9 Percent Hot Days (HD) correlated to dry vs wet areas [16]

- Hiyama et. al, [17] investigated the origins of rain- and subsurface waters of north-central Namibia's seasonal wetlands, analyzed natural stable water isotopes (SWIs) of hydrogen (HDO) and oxygen ($H_2^{18}O$)

> in rainwater, surface water and shallow groundwater. Rainwater samples were collected during every rainfall event of the rainy season from October 2013 to April 2014. The isotopic ratios of HDO and oxygen $H_2^{18}O$ were analyzed in each rainwater sample and then used to derive the annual mean value in precipitation weighted by each rainfall volume. Results showed that around three-fourths of rainwater was derived from recycled water at local–regional scales.

As another example, it is found that in large areas of the Southwest, evapotranspiration is virtually equal to 100 percent of the precipitation, which is only about 10 inches per year [12].

By contrast, in the conterminous United States, the estimated mean annual evapotranspiration is greatest in the Southeast (about 35 inches per year or about 70 percent of the precipitation), which is an area of abundant precipitation, permeable soils, and substantial solar radiation; it is least in the semiarid region of the Southwest where precipitation is limited. The ratio of estimated mean annual evapotranspiration to precipitation is least in the mountains of the Pacific Northwest and New England where evapotranspiration is about 40 percent of the precipitation [12].

Some efforts have been made to improve storm water innovation in RWM. The effort is called LID [18], "Low Impact Development (LID) is a planning and design approach that aims to mimic naturalized water balances. It combines infiltration, evaporation and transpiration while limiting runoff. The goal of LID is to restore processes that are lost in a built-up urban environment. LID includes several types of low-level new and innovative storm water technologies that together let water infiltrate the ground and evapotranspire into the air. However, no efforts have been made to cooling HHS.

4.1 RWM Effect on Oceans

Rising oceans' levels are anticipated with global warming due to the fact that the ocean expands as it warms. Its levels also will increase due to glacier melting. However, it doesn't help to have RWM also contributing from cities all over the world with water runoffs into the ocean. Prior to the industrial revolution, much of this water went to natural vegetation, streams and lakes. Urban and city are typically few degrees hotter and HHS-RWM may be instrumental in local water temperatures. RWM runoff into the ocean's of course also created a reduction of wet lands. Shifting precipitation from land to over oceans is a large concern. Most climate models do not agree on precipitation and drought areas as climate is hard to predict [19].

"The average of the models shows large increases in precipitation near the equator, particularly in the Pacific Ocean [19]"

It would be close to impossible to tell if RWM has a direct bearing on precipitation in certain areas. However, we have illustrated a number of studies that suggest logically that HHS-RWM is very important.

5. The Contention against CO_2 Feedback Being Solely Responsible for Specific Humidity Increase

There are certainly difficulties in understanding the CO_2 effect relative to moisture. Perhaps what is needed is a very good simulation experiment. Here are a number of common issues related to the strength of CO2:

- While there are an abundant number of CO_2 complex experiments in the literature, it is hard to point to a few that demonstrated simply that going from 300 to 400 ppm in the presence of about 25,000 PPM of moisture could produce the appropriate temperature rise.
- Climatologist claim that roughly 1/3 of the GW increase is due to CO_2. This is related to the contention that moisture increase from the ocean is a feedback mechanism not a forcing one [22-24]. In light of the conclusion of Sec. 2.3, we cannot ignore humidity is actually a forcing mechanism due to albedo decreases in roads and cities, which diminishes this feedback argument
- Authors have argued that CO_2 is about 400 PPM while water vapor, the stronger GH gas, averages around 25,000 ppm. This makes it hard to interpret.
- One can also estimate the fossil fuel contribution to global warming, and it is negligible since 1950. It adds <0.02 W/m2 out of the 4.1 W/m2 which would be the global warming energy change today. If one translates this in terms of CO_2 energy, the energy to create a CO_2 byproduct of fossil fuel increase from 300 to 400 ppm, is significantly small amount of creation energy compared to the global warming energy needed. That is, we have a miniscule amount of global warming energy creating CO_2 byproduct, which in turn is believed to create a major global warming energy change? Although the mechanisms are completely

different, it does show the difficulties in understanding how CO_2 could have such a GW amplification strength impact.

6. Summary - Solutions

From data and analysis, we do not anticipate that solving the CO_2 problem will fully stop global warming form occurring. We find that it is highly likely that HHS-HES areas and HHS-RWM are contributing to global warming, and that more studies are needed to assess the impact and how much it is contributing compared to the CO_2 feedback mechanism.

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 HES Effective Area Thought Experiment 1:

We take two identical pieces of asphalt having different albedos and areas. One is measuring 1 meter^2 while the second area is to be determined such that they both have the same evaporation rate when water is on the surface. The first asphalt piece is black and has an albedo of 0.05 while the second is painted white and has an albedo of 0.8. Then looking at the temperature profiles with about 1000 W/M^2 of sunlight falling on them, the temperature is approximated as

$$T_i(albedo) = \left(\frac{(1 - Albedo_i)Eo}{\sigma} \right)^{0.25} \quad \text{(A1)}$$

Taking E_o=1000W/m^2, then T(0.05)=360^{o}K=87^{o}C, and T(0.8)=340^{o}K=67^{o}C. This shows that we have 20^{o}C difference.

Below is a list of Albedo average values and associated temperatures in strong sunlight.

Table A1 Albedo of different surfaces and temperatures at 1000 W/m^2 for 1m^2 area

Surface	Albedo (0-1)	Temperature For 1M^2 at 1000 W/M^2
Water Type		
Snow	0.8	-29.5 C
Ice	0.6	16.7 C
Open Ocean	0.06	85.7 C*
Land Type		
Roads (0.04)	0.04	87.6 C
Urban Cov (0.12)	0.12	79.8 C
Forest (0.17)	0.17	74.7 C
Grass lands (0.26)	0.26	64.8 C

Desert (0.4)	0.4	47.6 C

*Actual temp. ~62C due to Ice effect

Consider now the general case with a piece of asphalt at temperature T, area A, material constant R_o in an environment with air pressure P, local relative humidity RH, and wind speed is r. Now consider a mass m of water spread uniformly on the surface. We then take the evaporation rate E for the non soluble surface approximated as

$$E = \frac{dm}{dt} = R_o A_i \exp\{-\frac{E_a}{K_b}(\frac{1}{T_i})\} f(P, RH, r) \tag{A2}$$

Here *f* is some function of the variables *P, RH,* and *r*. We take a second surface of the same material but at different temperature T and area A and look at the ratio of the evaporation rates yielding

$$E(2,1) = \frac{dm_2 / dt}{dm_1 / dt} = \frac{A_2}{A_1} \exp\{\frac{E_a}{K_b}(\frac{1}{T_{1Lower}} - \frac{1}{T_{2Upper}})\} \tag{A3}$$

Here we have held variable *P, RH, r,* and R_o left unchanged so they cancel. We allow $T_2 > T_1$. We then find that for A_1 to have the same evaporation rate as A_2 will occur when E(2,1)=1, so that A_1 is found just from the temperature rate as

$$A_1 = A_2 \exp\{\frac{E_a}{K_b}(\frac{1}{T_{1Lower}} - \frac{1}{T_{2Upper}})\} \tag{A4}$$

As an example, for typical water evaporation from a surface at temperature T, a common value for E_a=40.8KJ/Mole=0.423eV. Using the values found above for different albedo temperatures we had T(0.05)=360°K=87°C, T(0.8)=340°K=67°C, and inserting these values into the above equation gives

$$A_1 = 2.3\, A_2 \tag{A5}$$

Another way of saying this is that if we paint the asphalt a different color with an albedo of 0.8 compared with the typical value of black asphalt of 0.05, we actually make the area 2.3 times smaller in terms of evaporation rate which also impacts the time due to a cooler material with large specific heat. This also allows more time for water to run off and be stored in the land.

We can simplify this result and make a generalization from the above equation related to the effective area for evaporation between two surfaces, and this is

$$A_1 = (\tau_2 / \tau_1)\, A_2 \tag{A6}$$

Where τ_i is the evaporation time since the rate goes as the Arrhenius function, for the ith surface at different temperatures all other evaporation factors being the same.

This is an important relation for road design, if we can slow down the evaporation rate from a road, we can decrease its effective evaporation area. Besides albedo change, other design factors can be thought of such a water runoff to land, road irrigation, road water storage similar to soil, transpiration, material changes with lower specific heat capacity. Engineering roads to be more eco-friendly is one conclusion in this paper.

Appendix B- HES Area Effect Thought Experiment 2:

We take two surfaces, one with heat capacity C_{v1} and Area A1, and the second with C_{v2} and Area A2. Both surfaces are evaporating water and start at the same temperature, however we let $C_{v2}=2C_{v1}$. What is the equivalent area if they both are required to evaporate equally for the same time period.

Time to change Q is

$$t = \frac{Q}{P} = \frac{C_v m \Delta T}{P} = \frac{C_v m \Delta T}{pA} \tag{B1}$$

where Q is the change in heat occurring from ΔT change, m is the mass, P is the power in Watts, p is the sunlight power in W/m^2, A=Area. For example for asphalt C_v = 900 J/kg K, if m=1000Kg and ΔT=20K, then ΔQ=900 J/kg K x 1000Kg x 20K=18 E6 Joules. If 1000 W/m^2 falls on a 1 m^2 surface area then the time for this temperature change is

$$t = \frac{18E6J}{1000J/\sec} = 300\,\text{min} \tag{B2}$$

given that both areas have the same mass and same p, and both change by an amount ΔT then general

$$\frac{t_1}{t_2} = \frac{C_{v1}A_2}{C_{v2}A_1} \tag{B3}$$

if $C_{v2}=2C_{v1}$ then for $t_1=t_2$ we must have

$$A_1(C_{v1}) = 2A_2(2C_{v1}) \tag{B4}$$

Here we see that if Area A2 has a larger C_v, that evaporation times are only equivalent if A1 is larger proportionately. This can again be summarized by their evaporation times such that

$$A_1 = (\frac{t_1 C_{v2}}{t_2 C_{v2}})A_2 = (\frac{t_{1Cv}}{t_{2Cv}})A_2 \tag{B5}$$

Appendix C: HES Area Effect Thought Experiment 3

Consider now the complex case of a vegetative area being replaced by an asphalt highway. The specific heat of soil and mass can vary as water evaporates. This is untrue of asphalt. The specific heat of water is 4186 J/kg K compared to asphalt =900 J/kg K. We see that soil holds heat actually 4 times larger than asphalt. However, soil heat capacity varies with precipitation (soil dry=800, soil wet=1480 J/kg K). When it rains, the asphalt cools while it evaporates water. On the other hand, the rain cools the Earth at a faster pace since soil has a lower Cv and it is less conductive below the surface where th temperature is cooler. In order to evaporate from the soil in sunlight after it rains it takes time to heat the surface area. We see that the change in heat is a complex function of time as the soils mass and Cv changes with time.

$$\frac{d\Delta Q}{dt} = (dm/dt\, C_v + m\frac{dC_v}{dt})\Delta T \tag{C1}$$

To simplify the complex problem we take an average

$$\overline{\Delta Q} = \overline{mC_v}\Delta T \tag{C2}$$

Furthermore as water evaporates at the surface of the soil the stored water below diffuses to the top surface. Therefore the time is further lengthening by the diffusivity of water in the soil. So the equation is modified and simplified again so it is just a function of time to estimate the area ratios

$$A_1 = (\frac{t_1 \overline{DmC}_{v2}\overline{\Delta T}_2}{t_2 mC_{v2}\overline{\Delta T}_1})A_2 = (\frac{t_{1m\overline{DCv\Delta T}}}{t_{2mCv\Delta T}})A_2 \tag{C3}$$

The result demonstrates that the area effect can be simplified to the evaporation time. For example if water evaporates from a highway in 5 hours and on land the same amount of water evaporation takes 50 hours, then lost area is a factor of 10.

Appendix D – Earth's Energy Budget 2020 & 1950 Due to Slight Albedo Change

Earth's energy budget estimates when the albedo decrease from 0.29 [20] to 0.288 we get a 0.32°F temperature increase. This feeds the HHS across the globe from roads and cities.

<u>1950 Albedo=0.29 [20]</u>

Power Absorbed = 0.71 x 0.25x 1361 W/m2 =241.58 Watts/m^2

E=σT^4=241.58 W/m2 , T=255.5°K=0.2°F

<u>2020 Albedo=0.288</u>

Power Absorbed = 0.712 x 0.25 x 1361 W/m2 =242.26 Watts/m^2

E=sT^4=242.26 W/m2, T=255.66K=0.52°F

ΔT=0.32 °F increase in 2020

Appendix E 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 where the albedo decrease from 0.29 to 0.288, estimated between 2020 and 1950 respectively. Results of the simplified weighted model are given in Tables E1 and E2. Equation E1 is the weighted albedo by area, E2 is the weighted albedo with clouds.

$$Earth\ Weighted\ \ Albedo = \sum_i (\%\ Earth\ Area_i\ x\ Surface\ Item\ Albedo_i) \tag{E1}$$

$$Global\,Weighted\ Albedo = Average\{(Clouds\ Albedo\ x\,\%\ Coverage) + (Earth\ Weighted\ Albedo)\} \tag{E2}$$

Table E1: Albedo of 0.288 Year=2020

Surface	Enter % of Earth Area	Enter Albedo (0-1)	Weighted Albedo in % Results
Water	70.7		
Ice	9.8	0.6	5.88
Snow	11.6	0.8	9.28
Open Ocean	49.3	0.06	2.96
Land	29.3		
Roads (0.04)	0.8	0.04	0.03
Urban Cov (0.12)	1.2	0.12	0.14
Grass lands (0.26)	8.8	0.26	2.29
Forest (0.17)	8.6	0.17	1.46
Desert (0.4)	9.9	0.4	3.96
Sum % of Earth Area	100		
Weighted Earth			26.00
Clouds (0.47)	67	0.472	31.62
			Global Weighted Albedo in
Global=Average(Clouds & Weighted Earth) %			28.81
Global=Average(Clouds & Weighted Earth)			0.2881

Table E2: Albedo of 0.29, 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 F: Re-normalizing the Earth's Surface Albedo Area with Cities

We have described in Section 4 that the Earth's solar surface area has increased as cities are built. Essentially we have reshaped the Earth's surface with numerous tall buildings. We provided a crude example in Section 2.1 of how cities solar surface area might increase to 3% in 2019 from 1.2% in 1950. This would yield 101.8% increase in the Earth's surface area. Using the albedo model in Appendix E, Table E2 shows the original value that one might calculate for the Earth's albedo of 29% in the year 1950 [20] with a 1.2% solar surface area for urban coverage, while F1 shows the new albedo of 28.69 decrease with a renormalized urban area of 2.95% due to increase in city surface area in 2019. Table F2 shows a "what if" scenario in 2019. Here the albedo for roads and urban coverage were made more reflective to 50%. This would then impact the global albedo value to increase to 29.43%. These results demonstrate a number of important results shown in Table F3

- Actual shift from 1950 may be 0.5^{o}F (0.7-0.2) due to Cities & Road increases, which is 33% responsible for global warming in agreement with References 18-20.
- A "what if" results that shows if we changed the albedo to 0.5 of cities and roads, total shift is 1.3^{o}F {0.7-(-0.5). This almost solves global warming problem
- Due to improvements of specific humidity (see next section), it should actually solve most of the problem.

Overall this demonstrates that it would be non trivial to require that cities be mandated to improve their reflectivity requiring all buildings to has a higher albedo.

Table F1 2019 albedo value of 28.69%

Surface	Enter % of Earth Area	Enter Albedo (0-1)	Weighted Albedo in % Results
Water	69.45		
Snow	11.39	0.8	9.11
Ice	9.63	0.6	5.78
Open Ocean	48.43	0.06	2.91
Land	30.55		
Roads (0.04)	0.78	0.04	0.03
Urban Cov (0.12)	2.95	0.12	0.35
Forest (0.17)	8.45	0.17	1.44
Grass lands (0.26)	8.64	0.26	2.25
Desert (0.4)	9.72	0.4	3.89
Sum % of Earth Area	99.99		
Weighted Earth			25.75
Clouds (0.47)	67	0.472	31.62
			Global Weighted Albedo in %
Global=Average(Clouds & Weighted Earth) %			28.69
Global=Average(Clouds & Weighted Earth)			0.2869

Table F2: 2019 Albedo value of 29.43 if Roads and Cities reflectivity were 50%

Surface	Enter % of Earth Area	Enter Albedo (0-1)	Weighted Albedo in % Results
Water	69.45		
Snow	11.39	0.8	9.11
Ice	9.63	0.6	5.78
Open Ocean	48.43	0.06	2.91
Land	30.55		
Roads (0.04)	0.78	0.5	0.39
Urban Cov (0.12)	2.95	0.5	1.48
Forest (0.17)	8.45	0.17	1.44
Grass lands (0.26)	8.64	0.26	2.25
Desert (0.4)	9.72	0.4	3.89
Sum % of Earth Area	99.99		
Weighted Earth			27.23
Clouds (0.47)	67	0.472	31.62
			Global Weighted Albedo in %
Global=Average(Clouds & Weighted Earth) %			29.43
Global=Average(Clouds & Weighted Earth)			0.2943

Table F3 Summary of albedos in Tables F1-F3 and associated temperature energy budgets

Year	Surface Area of Cities	Albedo Roads	Albedo Urban Coverage	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} =σT^4

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

Example: If the ambient temperature when it rains is 27°C and 98%RH and the HHS surface temperature is 87°C (black asphalt, see Table A1), then the local relative humidity at the hotspot surface is reduced from 98%RH to 5.6%RH! Such cumulative effect from buildings and streets in a city likely will lower city's relative humidity compared to nearby rural areas. Studies could measure to see how dramatic this effect is.

The following equations were used for this estimate [21] HHS local %RH to 5.6%:

$$HHS_{RH} = RHamb\,\frac{P_{sat}(T_{amb})}{P_{sat}(T_{HHS})} \tag{G1}$$

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

$$P_{sat}(T) = e^{(a+\frac{b}{T}+\frac{c}{T^2}+\frac{d}{T^3})} \tag{G2}$$

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

If we have some average of local relative humidity mixed with the environmental average the new specific humidity x_{new} is

$$X_{New} = \frac{Q_{city}\,X_{city} + Q_{env}\,X_{env}}{Q_{city} + Q_{env}} \tag{G3}$$

where Q is the volume of air (m^3), Xs are the specific humidity or humidity ratio $kg_{water}/kg_{dry\text{-}air}$, which can be converted to relative humidity.

On average for large cities, these hotspots are likely to bring down the cities relative humidity. A lower relative humidity is correlated to more greenhouse gas in the atmosphere and global warming.

Appendix H: Evaporation Rate of Cities Vs. Ocean

The following formula is a simplified formula of the Evaporation Rate of Cities (Ec) vs that of the Ocean Eo, we make comparison between 1950 and 2020. We see that if the evaporation rate in cities is increasing, it may be more responsible for the added GH moisture gas in our atmosphere.

$$HHS_{effect-o}(1950) = \frac{E_O}{E_C} = \frac{A_O}{A_C} R(T_O,T_{HHS}) \frac{E_{WO}}{E_{WC}} \frac{RH_C}{RH_O} = 40.8x.46x20x0.5 = 188 \tag{H1}$$

and

$$HHS_{effect-o}(2020) = \frac{E_O}{E_C} = \frac{A_O}{A_C} R(T_O,T_{HHS}) \frac{E_{WO}}{E_{WC}} \frac{RH_C}{RH_O} = 16.3x.46x20x0.5 = 75 \tag{H2}$$

where

E_O,E_C=Evaporation Rate of Ocean, Evaporation Rate of Cities

AO, AC= Surface Area of Ocean, Area of City Surfaces (Ao/AC=49%/3%=16.3 in 2020, Ao/AC=49%/1.2%=40.8 in 1950)

R(T_O=60C,T_{HHS}=80)Acceleration temperature factor between Ocean and Cities (Arrhenius function) ~ 2.2

E_{WO}, E_{WC}= Percent of time surface exposed to water, E_{WO}=100%, E_{wc}=5% ~20

RH_C, RH_O=Local relative humidity of ocean and RH of city near surface ~40/80

This crude example illustrates the need for some studies. In 1950 the cities had a small effect of evaporation changes compared to cities in 2020. Results on this hypothetical example illustrate a factor of 2.5 higher 2020 compared to 1950 on the contribution to an increase in evaporation rate from cities over the ocean.

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