Hydro-Hotspots Global Warming

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DRAFT this paper is still in being updated

Abstract

Data on specific humidity shows it is increasing yearly while relative humidity is not following this trend. It is thought that global warming feedback is the key contributor. However, in this article we will show that hydro-hotspot emission likely plays a significant role. This is a term we denote in this paper for high evaporation rates from asphalt type roads and cities surfaces. We show in this article that such surfaces without proper irrigation drainage to soil areas have a very large effective evaporation area that is many times the size of the hotspot's area itself compared with higher albedo absorbing vegetative areas. Such high evaporation rates reduce water soil storage compared with say farm or grass land.

In climate change, we asked the question, what has historically changed? Without a full understanding of root causes, one cannot come up with proper solutions. We note that besides CO2, slight decrease in land albedo, there is a major change in the increase of specific humidity. This is thought to be an effect of CO2 global warming feedback where this warming causes an increase in evaporation and higher specific humidity which in turn acts as a greenhouse gas creating more warming. However we assert that at least part of the evaporation rate, must be due to the yearly increase in cities and roads expansions creating hydro-hotspot evaporation areas that we show has very high effective evaporation surface area. There is no doubt that such an effect would increase specific humidity. This then becomes an already absorbed greenhous gas in the lower troposphere capable of emitting back absorbed radiation.

1. Introduction - Hydro-Hotspots High and Related Data

In this paper we look at an effect we term hydro-hotspot creating greenhouse water vapor gasses and in turn global warming feedback. This is the effect that roads and cities have on climate change related to loss of soil moisture storage and high evaporation rates during precipitation periods emitting effectively hot moisture greenhouse gas that re-radiates in part back down creating global warming.

By way of introduction, we visualize the following hydo-hotspot feedback contribution to global warming.:

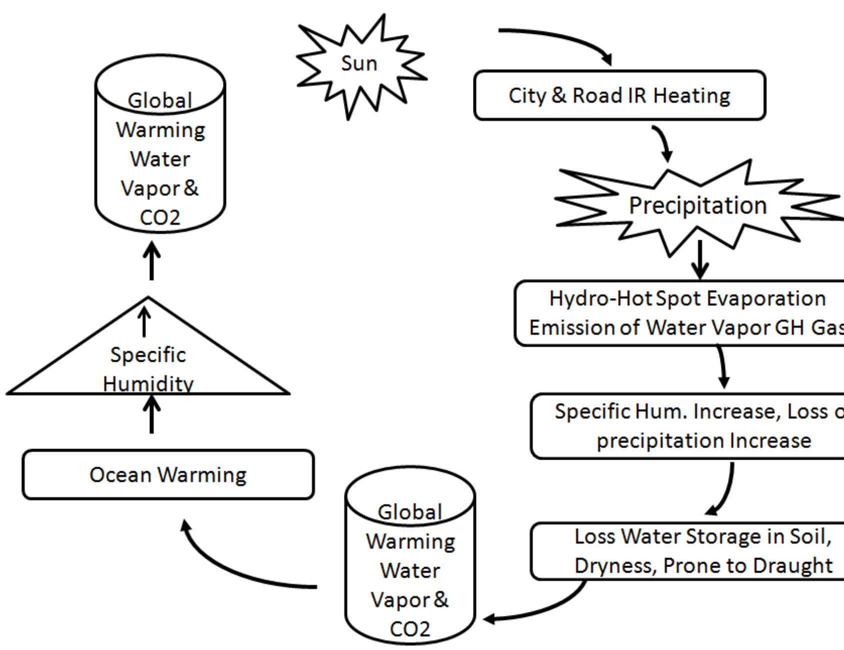


Figure 1 Hydro-hotspot feedback view of contribution to global warming

The Effect of Hydro-Hotspots feedback can be summarized from Figure 1:

- Low albedo cities and roads absorbing sun light and emitting IR
- Precipitation occurs, followed by evaporation of hydro-hotspot greenhouse moisture
- Observed increase in the specific humidity and lower relative humidity, along with CO2 increases
- Loss of water storage due to replacement of vegetative areas with cities and roads
- Increase in local dryness and some correlation to the eventual potential for draught
- Global warming increase due to higher specific humidity and CO2 increase including ocean temperature rise creating more evaporation and higher specific humidity
- More greenhouse gas in the form of moisture and eventual further warming.

In Section 2 we discuss the contention that the rise in CO2 is responsible for a feedback mechanism primary responsible for the observed rise in specific humidity. We provide an overview for the contention that perhaps hydro-hotspots is a major contributor. As well in Section 5 we further argue that the CO2 feedback mechanism is not as strong as one might imagine. This leads to the conclusion that hydro-hot spots could be a major contributor to global warming. In Section 3 we overview relevant data. In Section 4 we describe a simplified expression for the hydro-hotspot effective area and provide a brief summary in Section 6.

2. Specific Humidity Sources Ocean vs Asphalt

The key issue on specific humidity is where has the increase humidity come from and how do we account for the global warming trends. It is thought that CO2 initially increases the temperature, then increases the specific humidity primarily due to ocean temperature rise, then a new temperature occurs from the increase in specific humidity. It is this feedback mechanism that climatologist claim is entirely responsible for the increase in specific humidity and subsequent justified the full temperature increase. Yet we know two things, part of the CO2 must emit away from the earth, furthermore, there is a high probability that any CO2 emission that is emitted gets re-absorbed by other CO2 molecules since there is a narrow absorption wavelength (about 15um).

One could certainly argue that this feedback mechanism increases specific humidity from ocean global warming. Such a correlation was described in by [1,2,3]. However, these authors view the correlation with CO2 creating warming to the ocean as a cause from warming rather than other sources to specific humidity as presented here. They look at yearly trends in CO2 which has a similar trend to global warming yearly increase. As well they look at complex data sets and have not reviewed observed effective loss of land related to soil moisture, land albedo decrease, and increase in highways and city areas effects that are also affecting specific humidity. In fact, one could similarly show a correlation chart of global warming and increase Asphalt usage! What is hidden is effective hydro-hotspot area. Since the area of roads and cities is small (<2% of the Earth Surface), possibly some may have thought that such surfaces have negligible impact. This is an incorrect assumption. We show that hydro-hotspots have a very high effective area effect. Many times the size of the area itself as it is related to the evaporation rate difference between adjacent soil and say asphalt.

With this understanding, we consider the possibility that loss of soil moisture storage and high evaporation rates in cities, streets and highways, contribute significantly to greenhouse water vapor gasses and global warming. Water vapor is known to dominate greenhouse temperatures effects [3, 4]. Such an inference would then create a strong feedback mechanism as illustrated above.

3. Hydro-hotspot Supporting Related Data Trends

The following data and analysis is summarized that supports Hydro-hotspot feedback:

- **Hydro-hotspot area effect**: A simplified analysis is presented in Section 4 illustrating when all things are equal, the area lost from soil water storage due to roads, for example is given primarily by the differences in evaporation times between the would be vegetative area and its city or road replacement area. For 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, specific humidity and global warming emitted hot greenhouse gase.

- **Specific Humidity Rising:** Figure 2 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 1970s (specific humidity is rising) [5], while the atmosphere over land is becoming less saturated (relative humidity is dropping) [5].

- **Precipitation:** Figure 2 illustrates that precipitation has remained constant [5] even though the specific humidity has increased. This seems to indicate that the evaporated water vapor in the air is not contributing to precipitation. However in Fig. 7 and 8 we see that in later years it is actually increasing.

- **Soil Moisture:** Figure 3 shows a decrease in soil moisture [5] likely suggesting a correlation to global warming. This increase in dryness is made worse from the high evaporation rates from cities and roads increasing over time.

- **Albedo decline:** In Figure 4, a decline in land albedo [5] is found. One would expect this to decrease to occur along with an increase in roads in city areas which have a much lower albedo value than natural vegetative areas. Global albeto loss has been blamed on glacier loss but here it is illustrated just for land.

- **Increase in Asphalt use:** Figure 5 and 6 show an increase in Asphalt use (2009-2012) and increase in highway miles (1923-2009), respectively [6,7]. Although the data is limited on asphalt and highway growth, the trend is clear. Climatologist correlate the rising CO2 greenhouse gas to global warming. Here one could just as well correlate the rising use of Asphalt to global warming via the related hydro-hotspot effect and emission of greenhouse water vapor gas**.**

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

The primary effect that we are looking at with respect to data is possible contribution to the evaporation rate and its effect to the rising specific humidity in the troposphere (lower 10 miles of atmosphere). Other related effects is that are relevant which we will discuss is related dry condition that are a necessary but not sufficient condition for draught. Hot road also expand air and not only drive up specific humidity but lower %RH. One other critical effect that is hard to calculate is loss of plant water storage which is released in draught conditions or when plants die.

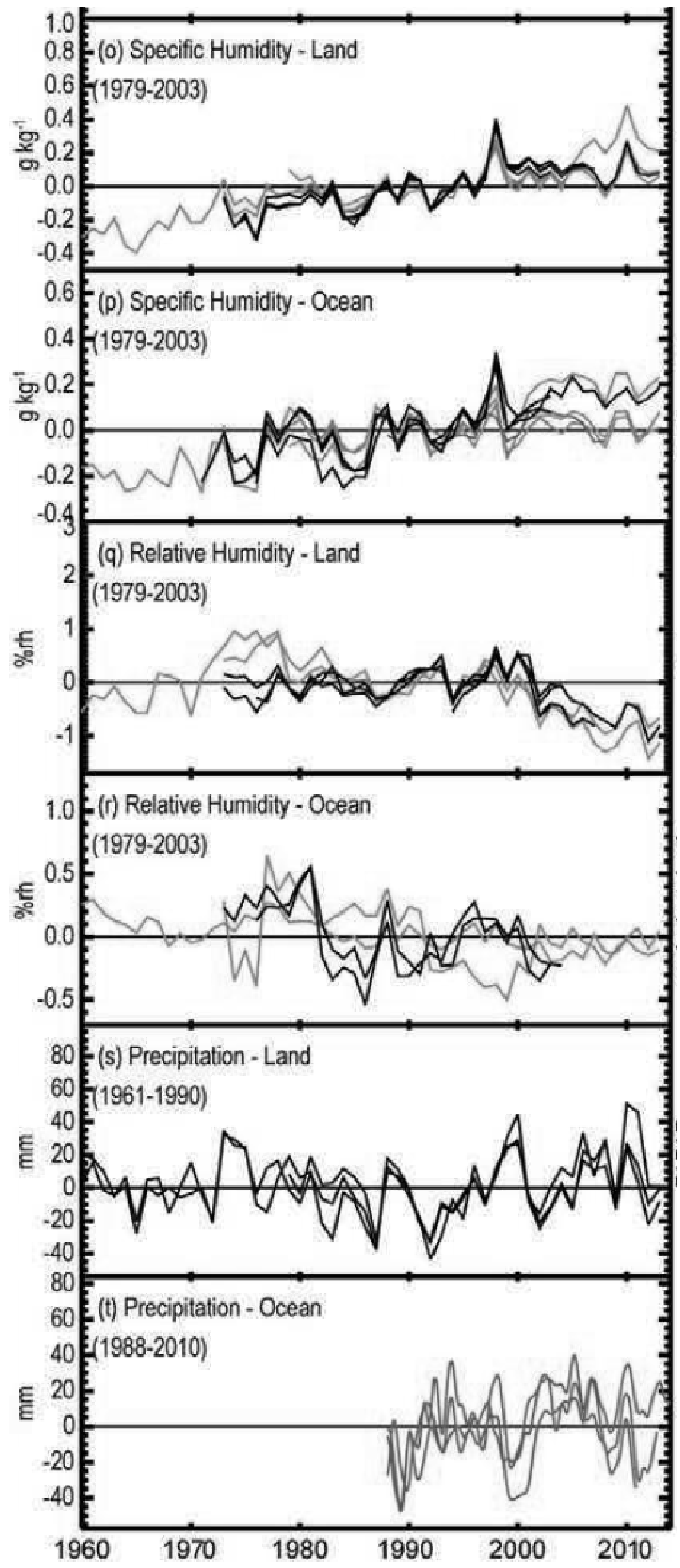


Figure 2 Top two figures show the specific humidity over land and water both increase while the third figure showing the relative humidity decreasing trend primarily over land while the ocean is more stable but likely harder to measure. Lastly the bottom two figures show a fairly constant precipitation rate in view of the fact that the specific humidity is increasing [5]. In later years Fig. xyz below shows precipitation eventually increasing.

K. Willett, A. Simmons, and D. Berry, 2014: [Global climate] Surface humidity [in "State of the Climate in 2013"]. Bull. Amer. Meteor. Soc., 93 (7), S19–S20.

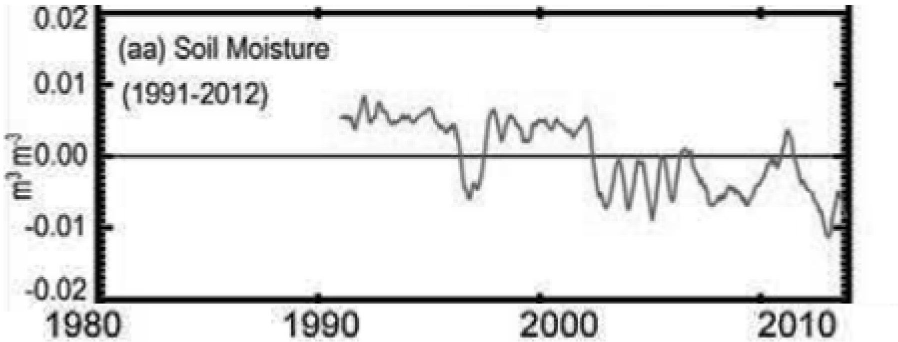


Figure 3 Loss of soil moisture likely due to global warming over land [5]

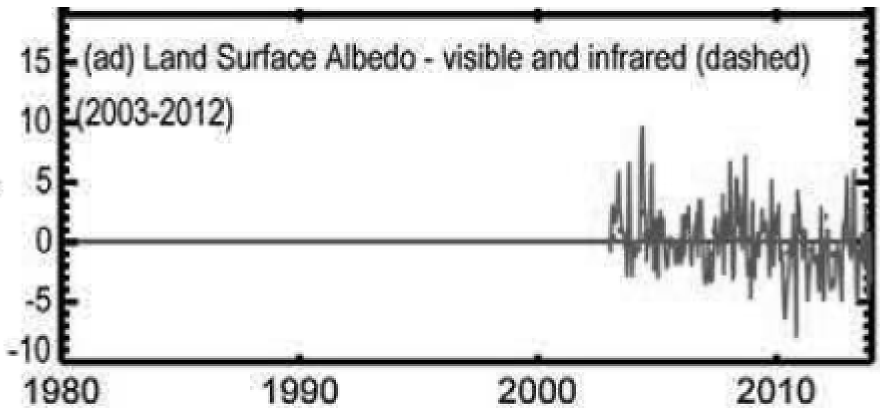


Figure 4 Loss of albedo over land likely due to increase in cities and highways [5]

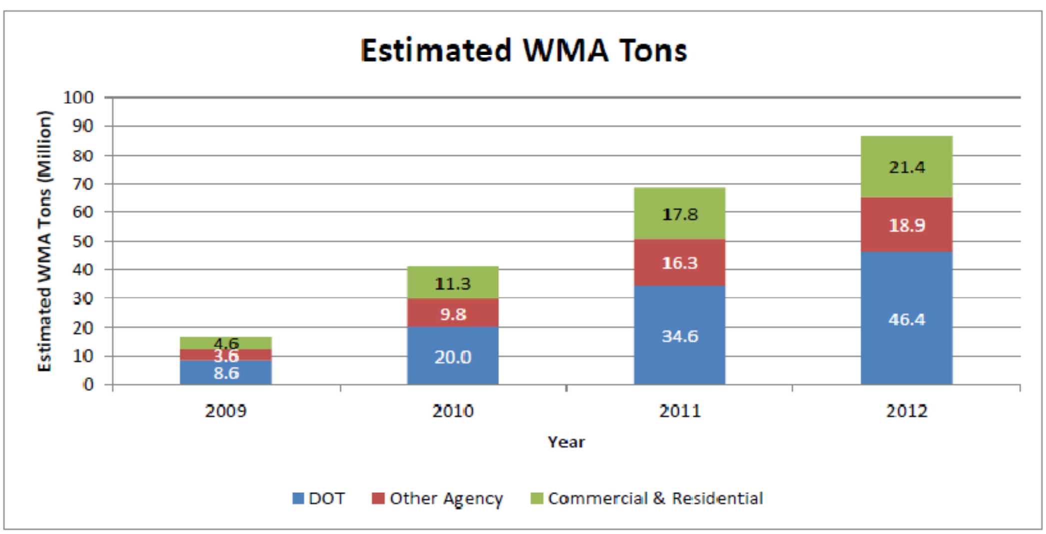
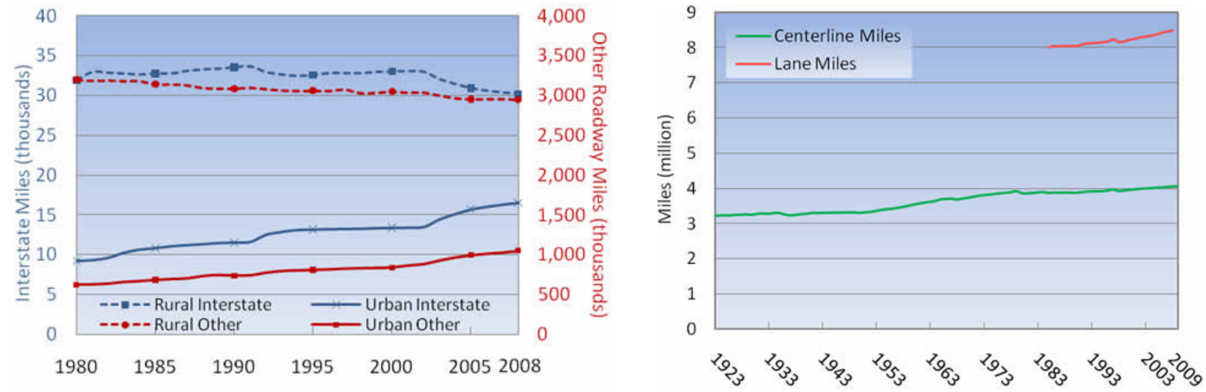


Figure 5 Growth of Warm Mixed Asphalt Usage per year (2009-2012) in USA [6]

Ref. K Hansen, A. Copeland, Annual Asphalt Pavement Industry Survey on Recycled Materials and Warm-Mix Asphalt Usage: 2009-2012 National Asphalt Pavement Assoc. Dec 2013



(a) (b)

Figure 6 Interstate Miles versus yearly increase in US [7] .

Ref. US DOT, Fed Highway Admin., Highway Finance Data Collection, *Data Source: FHWA, Office of Bridge Technology, National Bridge Inventory*
2011https://www.fhwa.dot.gov/policyinformation/pubs/hf/pl11028/chapter1.cfm

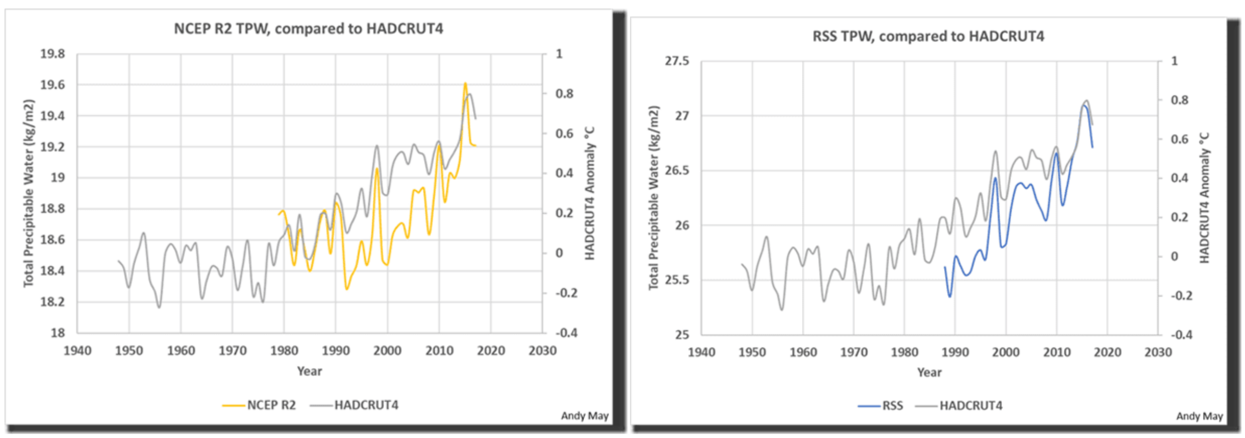


Figure 7 Specific humidity and global warming trends from two different agencies [8]. Here the author does not differentiate between specific humidity and precipitation.

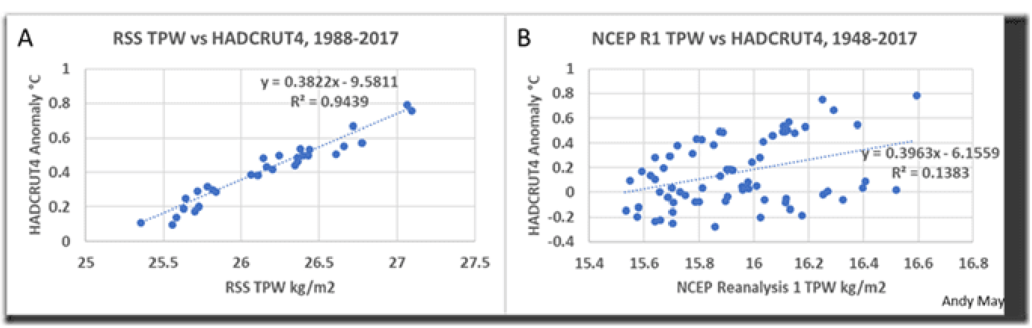


Figure 8 Correlation of specific humidity - Total Precipitation Water (TPW) for different data sets with global warming [8]. Here the author does not differentiate between specific humidity and precipitation.

4. Hydro Hotspot Effective Area of Evaporation

In this section we provide a simplified expression for the equivalent hydro-hotspot area found in the appendix A, B, C and is roughly given by

$$A_{EfHS} = (\frac{t_{Soil}}{t_{HS}})A_{Soil} = (\frac{t_{Soil}}{t_{HS}})(A_{HS} - A_{HS-\%IG})$$

Where

A_{EfHS}=Effective hot spot area,

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

A_{HS} hotspot area subtracte from

$A_{HS-\%IG}$ any % run off or irrigated of water falling on the road and

tSoil is the evaporation time of the soil

t_{HS} is the evaporation time of the Asphalt surface after precipitation occurs.

.The factor $(\frac{t_{Soil}}{t_{HS}}) = \Delta R$ provides a rate change related to time rate of change which is shown in the appendix as a function of

ΔR{(Exp-(E_a/k_B T)), average soil vs asphalt specific heat Cv, dCv/dt, dm/dt, average ΔAlbedo, soil Diffusion rate, Evapotranspiration }

5. The argument against CO2 feedback for specific humidity

Here we provide an argument that the increase in specific humidity cannot be solely due to C02 feedback.
Outline
How to account for increase specific humidity from CO2 emissions

1) Key problem is 50% of the emissions emit away from earth
2) The emitted CO2 radiation is narrow band 15 um with some spectral width
3) A portion of this radiation is likely re-absorbed by other CO2, say 25%
4) Then a portion is absorbed by water vapor in the atmosphere say 40%
5) A portion of 3 and 4 are re-radiated away from earth 50%
   This leaves 0.5 x 0.75 x 0.4 x 0.5 = 7.5% reaching the lower troposphere and earth for global warming and increasing ocean temperatures enough to raise specific humidity

6. Summary

We find that it is highly likely that hydro-hot spots are contributing significantly to global warming and perhaps at a much higher percentage that CO2. Further studies are needed to explore this conclusion.

References

[1] Michael P. Byrne and Paul A. O'Gorman Trends in continental temperature and humidity directly linked to ocean warming, Proc. Of the National Academy of Sciences, April 23, 2018. https://www.pnas.org/content/115/19/4863

[2] AE Dessler, Z Zhang, P Yang, Water-vapor climate feedback inferred from climate fluctuations, 2003–2008, - Geophysical Research Letters, 2008, Wiley Online Library

[3] **AE** Dessler , Observations of **climate** feedbacks over 2000–10 and comparisons to **climate** models, **Journal of** Climate**, 2013**

[4] A.E. Dessler, The physics of climate change, Dept of Atmosphere Science, Texas A&M Univ, Sept. 25, 2015, Youtube.

[5] K. Willett, A. Simmons, and D. Berry, 2014: [Global climate] Surface humidity [in "State of the Climate in 2013"]. Bull. Amer. Meteor. Soc., 93 (7), S19–S20.

[6] K Hansen, A. Copeland, Annual Asphalt Pavement Industry Survey on Recycled Materials and Warm-Mix Asphalt Usage: 2009-2012 National Asphalt Pavement Assoc. Dec 2013

[7] US DOT, Fed Highway Admin., Highway Finance Data Collection, *Data Source: FHWA, Office of Bridge Technology, National Bridge Inventory* 2011
https://www.fhwa.dot.gov/policyinformation/pubs/hf/pl11028/chapter1.cfm

Appendix In Development

Appendix A

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. When sun falls of these at about 1000 W/M2, we find in appendix A that the areas goes as the time of evaporation such that

We first look at the temperature profiles with about 1000 W/M^2 of sunlight falling on them. The temperature is approximated as

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

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.

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, 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 such a non soluble surface approximated as

$$E = \frac{dm}{dt} = R_o A_i \exp\{-\frac{E_a}{K_b}(\frac{1}{T_i})\} f(P, RH, r) \tag{2}$$

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 given by

$$E(2,1) = \frac{dm_2 / dt}{dm_1 / dt} = \frac{A_2}{A_1} \exp\{\frac{E_a}{K_b}(\frac{1}{T_{1Lower}} - \frac{1}{T_{2Upper}})\} \tag{3}$$

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

$$A_1 = A_2 \exp\{\frac{E_a}{K_b}(\frac{1}{T_{1Lower}} - \frac{1}{T_{2Upper}})\} \tag{4}$$

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

$$A_1 = 2.3\, A_2 \tag{5}$$

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. 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

$$A_1 = (\tau_2 / \tau_1)\, A_2 \tag{6}$$

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, material changes with lower specific heat capacity. Engineering roads to be more eco-friendly is one conclusion in this paper.

Appendix B

Thought Experiment 2:

We take two surfaces, one with heat capacity Cv1 and Area A1, and the second with Cv2 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 at the same time.

Time to change Q is

$$t = \frac{Q}{P} = \frac{C_v m \Delta T}{P} = \frac{C_v m \Delta T}{pA} \tag{7}$$

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/m2, A=Area. For example for asphalt Cv = 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/m2 falls on a 1 m2 surface area then the time for this temperature change is

$t = \dfrac{18E6J}{1000J/\sec} = 300\min$.

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

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

if Cv2=2Cv1 then for t1=t2 we must have

$$A_1 (C_{v1}) = 2 A_2 (2C_{v1}) \tag{5}$$

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

$$A_1 = (\frac{t_1 C_{v2}}{t_2 C_{v2}}) A_2 = (\frac{t_{1Cv}}{t_{2Cv}}) A_2 \tag{8}$$

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. DfRSoft provides consulting in reliability and shock and vibration, training classes and DfRSoftware. Please contact us if you need help. Alec has provided reliability engineering services in diverse industries (AT&T Bell Labs, Tyco Electronics, HP, NASA, etc) for over 35 years in aerospace, automotive and electrical and mechanical systems. He has provided training classes in Design for Reliability & Quality, Shock and Vibration, HALT and ESD. Alec has presented numerous technical papers and won the 2003 RAMS best tutorial award for the topic, "Thermodynamic Reliability Engineering."