Global Warming Due to Highly Evaporating Surfaces

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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 discuss the possible contribution from Highly Evaporating Surfaces (HES) that likely contribute to Global Warming problems. We describe high evaporation surface rates during precipitation periods from areas like 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 evaporation rate, and their effective area is many times the size of the HES area itself compared with higher albedo absorbing vegetative areas that also include transpiration. Such high evaporation rates tax the atmosphere often with high kinetic energy molecules in the troposphere and have replaced vegetative areas so there is significant reduction of water soil storage compared with vegetative soil areas.

An understanding root causes, is always needed to find proper solutions. Therefore, we start in climate change, by asking the question, what has historically changed? We note that besides CO_2, slight decrease in land albedo, there is a major change in the increase of specific humidity. This is thought to be an effect of CO_2 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 HES areas that we show has very high effective evaporation surface areas. There is no doubt that such an effect would increase specific humidity. This then contributes as a greenhouse gas in the lower troposphere. One key question is the contribution significant and we will show that it is possibly a major issue.

1. Introduction - Highly Evaporation Surface Feedback

In this paper we look at an effect of Highly Evaporating Surfaces (HES) 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 also often emitting from hot surfaces like asphalt and taxing the atmosphere with hot moisture greenhouse gas with high kinetic energy molecures that contributes to lowering the relative humidity and increasing the specific humidity which may significantly contribute to global warming.

Figure 1 illustrates how HES feedback would contribute to global warming:

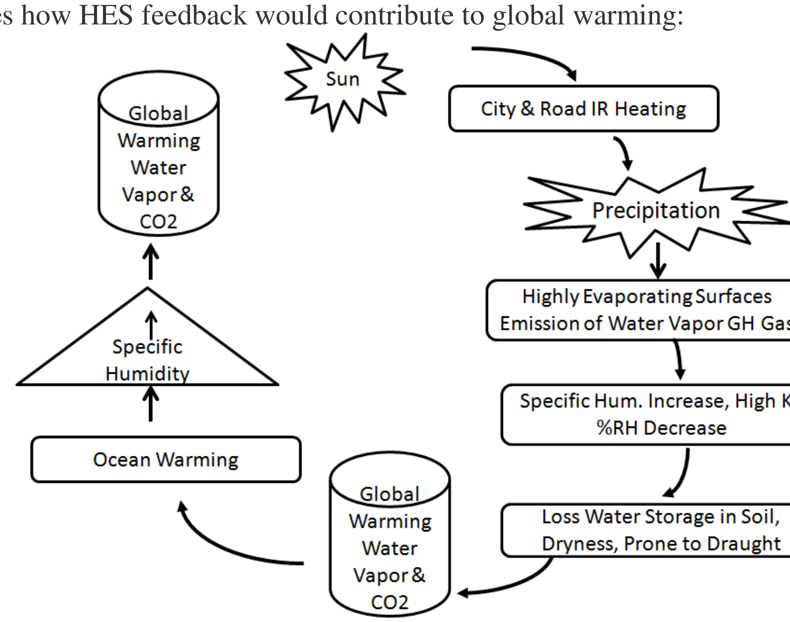


Figure 1 Highly Evaporating Surfaces feedback view of contribution to global warming

Figure 1 may be summarized as follows:

- Low albedo cities and roads absorbing sun light and emitting IR
- Precipitation occurs, followed by evaporation of HES moisture often with high KE
- Observed increase in the specific humidity and lower relative 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 draught
- Global warming increase due to higher specific humidity and the known CO_2 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 theory that the rise in CO_2 is responsible for a feedback mechanism responsible for the observed rise in specific humidity. We provide an overview of how HES may be a significant contributor as well. Furthermore, in Section 5 we argue that the CO_2 feedback mechanism may not fully responsible for specific humidity rise. This leads to the conclusion that HES 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 HES evaporation rates and its effective area and provide a brief summary in Section 6.

2. Specific Humidity Sources - Ocean vs. HES

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 CO_2 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 full temperature increase. Yet we know two things, part of the CO_2 must emit away from the earth, furthermore, there is a high probability that any CO_2 emission gets re-absorbed by other CO_2 molecules since there is a narrow absorption wavelength (about 15um), then re-admits 50% towards Earth.

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 CO_2 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 CO_2 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 area effects that are also increasing specific humidity from HES'. In fact, one could similarly show a correlation chart of global warming and increase to Asphalt usage! What is hidden is effective HES 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 may be an incorrect assumption. We show that HES have a very high effective evaporation area. Many times the size of the area itself as it is related to the evaporation rate differences between adjacent soil and say asphalt. They also sometimes emit vapor with high kinetic energies (KE) impacting the relative humidity and vapor pressure.

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. HES Supporting Related Data Trends

The following data and analysis is summarized that supports HES feedback:

- **HES 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 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. 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, then the effective soil land lost is a factor of 24 times, contributing to the evaporation rate, specific humidity and global warming emitted moisture greenhouse gas. This doesn't even consider transpiration.

- **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 HES areas in cities and roads increasing over time.

- **Albedo decline:** In Figure 4, a decline in land albedo [5] 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 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 CO_2 greenhouse gas 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**.**

- **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 are likely dry conditions 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 and transpiration. This rate also changes with warming trends.

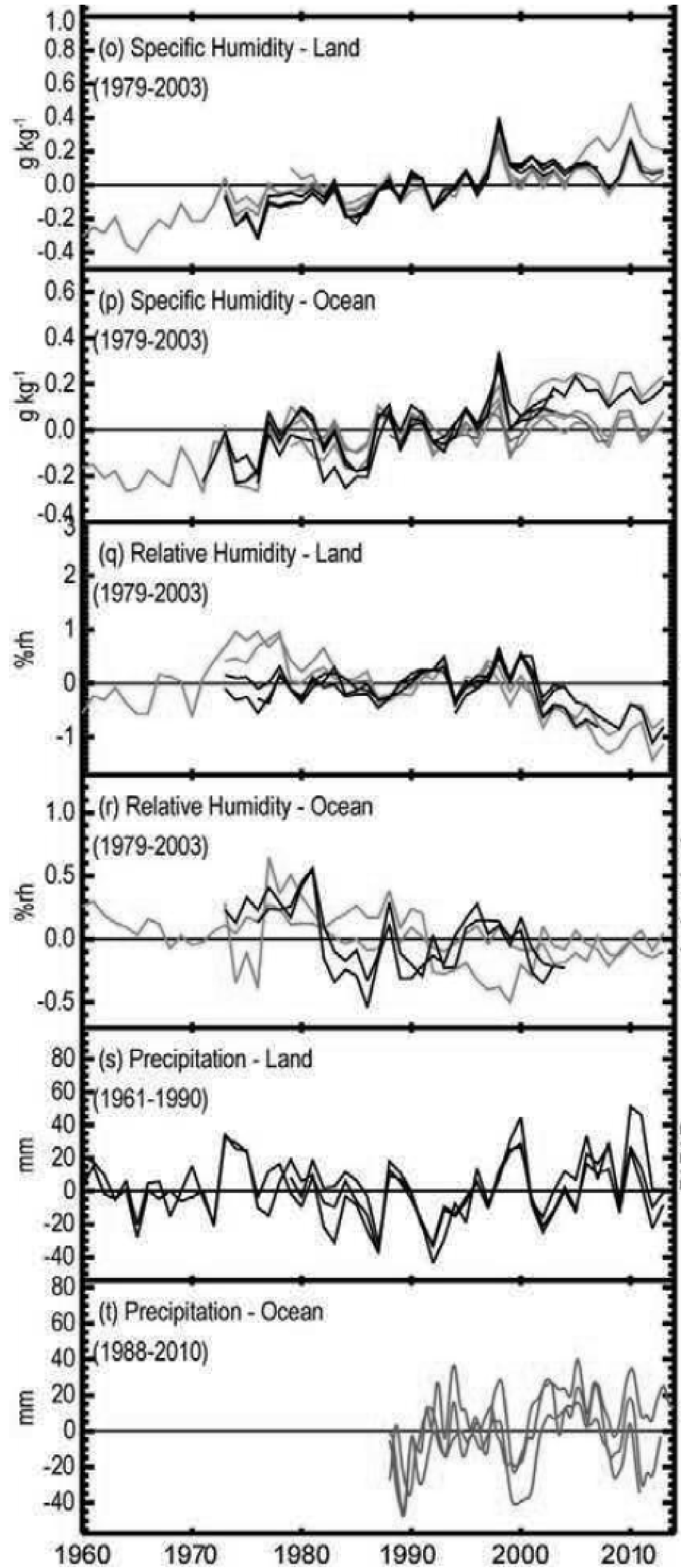


Figure 2 Top two figures show the specific humidity over land and water both increase while the third figure showing the relative humidity decreasing trend primarily over land while the ocean is more stable but likely harder to measure. Lastly the bottom two figures show a fairly constant precipitation rate in view of the fact that the specific humidity is increasing [5]. In later years Fig. 7, shows precipitation eventually increasing.

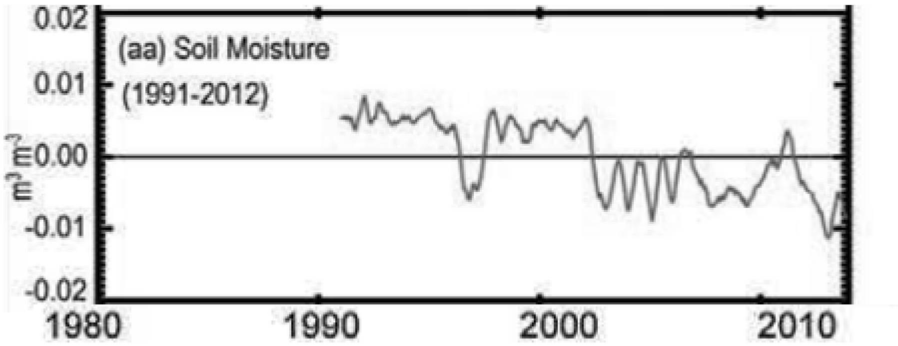


Figure 3 Loss of soil moisture likely due to global warming over land [5]

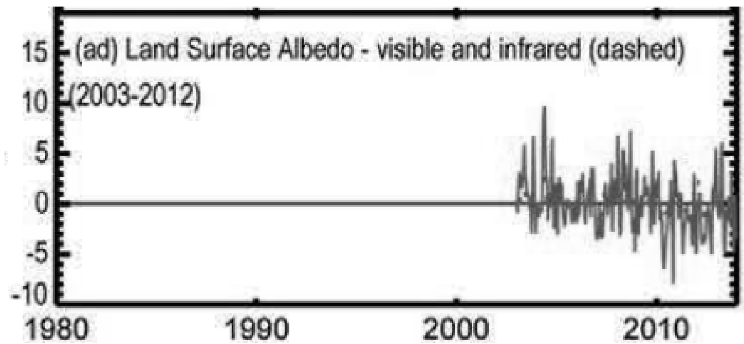


Figure 4 Loss of albedo over land likely due to increase in cities and highways [5]

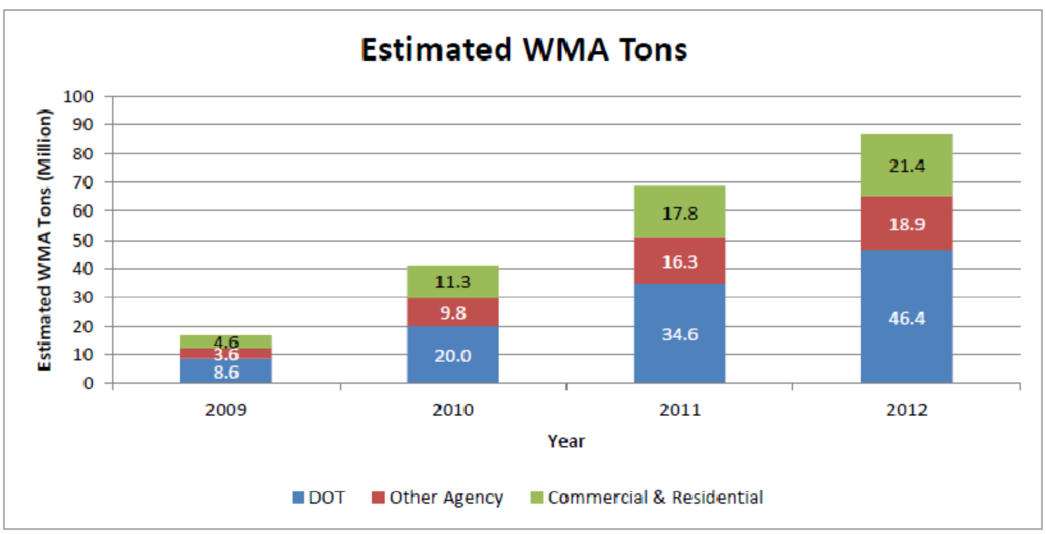
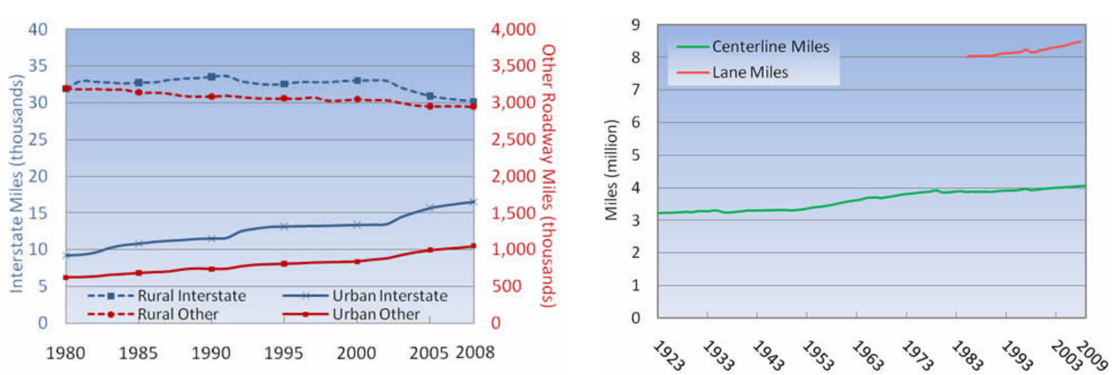


Figure 5 Growth of Warm Mixed Asphalt Usage per year (2009-2012) in USA [6]



(a) (b)

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

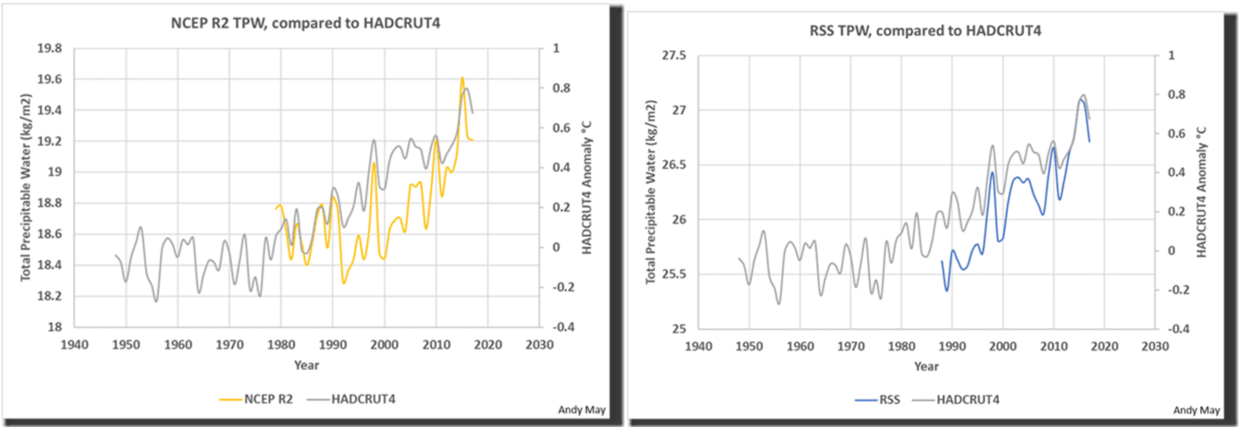


Figure 7 Specific humidity and global warming trends from two different agencies [8]. Here the author does not differentiate between specific humidity and precipitation.

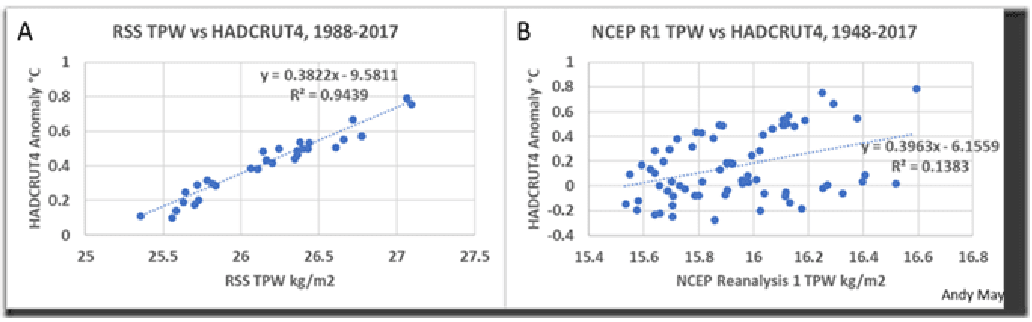


Figure 8 Correlation of specific humidity - Total Precipitation Water (TPW) for different data sets with global warming [8]. Here the author does not differentiate between specific humidity and precipitation.

4. HES Effective Area of Evaporation

In this section we provide a simplified expression for the equivalent HES area found in the Appendices A, B, and 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

t_{Soil} 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 an evaporation rate related to time rate of change which is shown in the appendix 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}

5. The Contention Against CO2 Feedback Being Solely Responsible for Specific Humidity Increase

Here we provide some contention that an increase in specific humidity cannot be solely due to CO_2 feedback.

How to account for increase specific humidity from CO_2 emissions

1) Ocean area for heating 68.7%
2) Emissions towards Earth 50%
3) The emitted CO_2 radiation is narrow band 15 um with some spectral width. Only a portion of this radiation is likely re-absorbed by other CO_2, say 25%
4) Then a portion is absorbed by water vapor in the atmosphere say 60%
5) A portion of 3 and 4 are re-radiated away from earth 50%
   This leaves 0.687 x 0.5 x 0.75 x 0.4 x 0.5 = 5.2% reaching the lower troposphere and earth for global warming and increasing ocean temperatures enough to raise specific humidity

6. Summary - Solutions

We find that it is highly likely that HES areas 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.

HES Reduction Solutions

- Further studies required in this area to understand the effect and its contribution to GW
- Change Albedo of Roads Reducing KE of molecules and allowing for increase in irrigation time
- Reduce driving speeds during rain to reduce evaporation rates
- Improve HES irrigation to soil
- Improve vegetation in run off areas, plant millions of trees in HES areas
- Require negative population growth to reduce increase HES surfaces

References

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[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. Then looking at the temperature profiles with about 1000 W/M^2 of sunlight falling on them, the temperature is approximated as

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

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 the non soluble surface approximated as

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

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 yielding

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

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

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

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^{o}K=87^{o}C, T(0.8)=340^{o}K=67^{o}C, and inserting these values into the above equation gives

$$A_1 = 2.3\, A_2 \quad (5)$$

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

$$A_1 = (\tau_2 / \tau_1)\, A_2 \quad (6)$$

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, transpiration, 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

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

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

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

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

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

Thought Experiment 3

Consider now the complex case of a vegetative area being replace 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 hold heat actually 4 times larger than Asphalt. However, soil varies with mass. 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 low Cv and the temperature is cool. 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.*

$$\frac{d\Delta Q}{dt} = (dm/dt\, C_v + m\frac{dC_v}{dt})\Delta T \tag{9}$$

To simplify the complex problem we take an average

$$\overline{\Delta Q} = \overline{m}\overline{C_v}\Delta T \tag{10}$$

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

$$A_1 = \left(\frac{t_1 \overline{DmC}_{v2} \overline{\Delta T}_2}{t_2 m C_{v2} \overline{\Delta T}_1}\right) A_2 = \left(\frac{t_{1 \overline{m} \overline{D} \overline{C} v \Delta T}}{t_{2 m C v \Delta T}}\right) A_2$$

The results 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.

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. 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."