Climate Change Mitigation Potential of Pavement Albedo

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PROBLEM

Albedo is the measure of how much solar energy is reflected by the Earth's surface. Lighter color, or high-albedo, surfaces absorb less sunlight energy and reflect more shortwave radiation. Increasing pavement albedo has been considered as a technological strategy to mitigate impacts of climate change through a mechanism known as radiative forcing. Studies have applied simple analytical models to quantify the impact of changes in land cover on global climate. However, gaps exist in regards to quantifying the transmittance of radiation through the atmosphere and due to uncertainties with variations in time and space. In fact, the radiative forcing impact due to pavement albedo enhancement for a specific location depends largely on local radiation intensity and atmospheric conditions, which are affected by context-specific factors such as solar angle, water content, and the presence of small atmospheric particles called aerosols.

APPROACH

We developed an analytical approach to quantify global warming potential (GWP) savings due to increases in pavement albedo. The approach was adapted from a model-based parameterization *(1)* and used location-specific data on incoming solar radiation at the earth's surface and at the top-of-atmosphere (TOA), accounting also for cloud fraction as well as solar zenith angle (angle between the sun and the vertical). We used the approach to estimate GWP savings by modeling an albedo increase for all pavements in the US as a means of obtaining an upper bound on the potential of pavement albedo to mitigate the impacts of climate change. We assumed an increase in 0.2 at the beginning of the analysis period, and further assumed that the albedo change would decay to 0.1 as pavements wear off over time. We obtained data from 2016 FHWA Highway Statistics on total lane-miles of pavements by state *(2)*, and multiplied them by the corresponding GWP savings per square meter of pavement, which were calculated from our adapted location-specific model, to obtain annual GWP savings at a state level.

FINDINGS

See figure 1, page 2. As the map demonstrates, the variation in GWP savings across the country is dependent on location and climate zone, which are factors that drive context-specific RF impact. The number of lane-miles of pavements in a given state is also significant. In general, states in the southern U.S. have a larger potential for GWP savings from RF due to pavement albedo enhancement. The benefit decreases from south (for Texas 4.429 kg $CO_{2\text{-eq}}$ normalized to 1 m^2 of pavement) to north (for Minnesota 3.123 kg $CO_{2\text{-eq}}/m^2$) because pavement surfaces in northern states receive less solar radiation. Texas exhibits the greatest GWP savings (3,112 kton CO_2-eq). If all urban and rural roads in the Continental United States were converted to reflective pavements, savings would equal 34,703 kilotons in CO_2 emissions per year. According to U.S.

WHY DOES THIS RESEARCH MATTER?

- There is significant potential for pavements to mitigate the impacts of climate change.
- Evaluating the effectiveness of pavement albedo enhancement strategies (changing surface reflectivity) requires context-specific data on climate conditions, including factors such as incoming solar radiation, solar angle, and cloud cover.
- Researchers developed an approach to quantify global warming potential savings due to increases in pavement albedo

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EPA's greenhouse gas equivalencies calculator *(3)*, that's the equivalent of removing 666,381, or 8 percent, of passenger vehicles from Texas roads for one year. Nationwide, the savings would be equivalent to removing nearly 7.4 million, or roughly 7 percent, of passenger vehicles. A granular analysis at the county level greatly improves the precision of the results. Detailed results of the analysis can be accessed interactively via a Tableau workbook posted at this link.

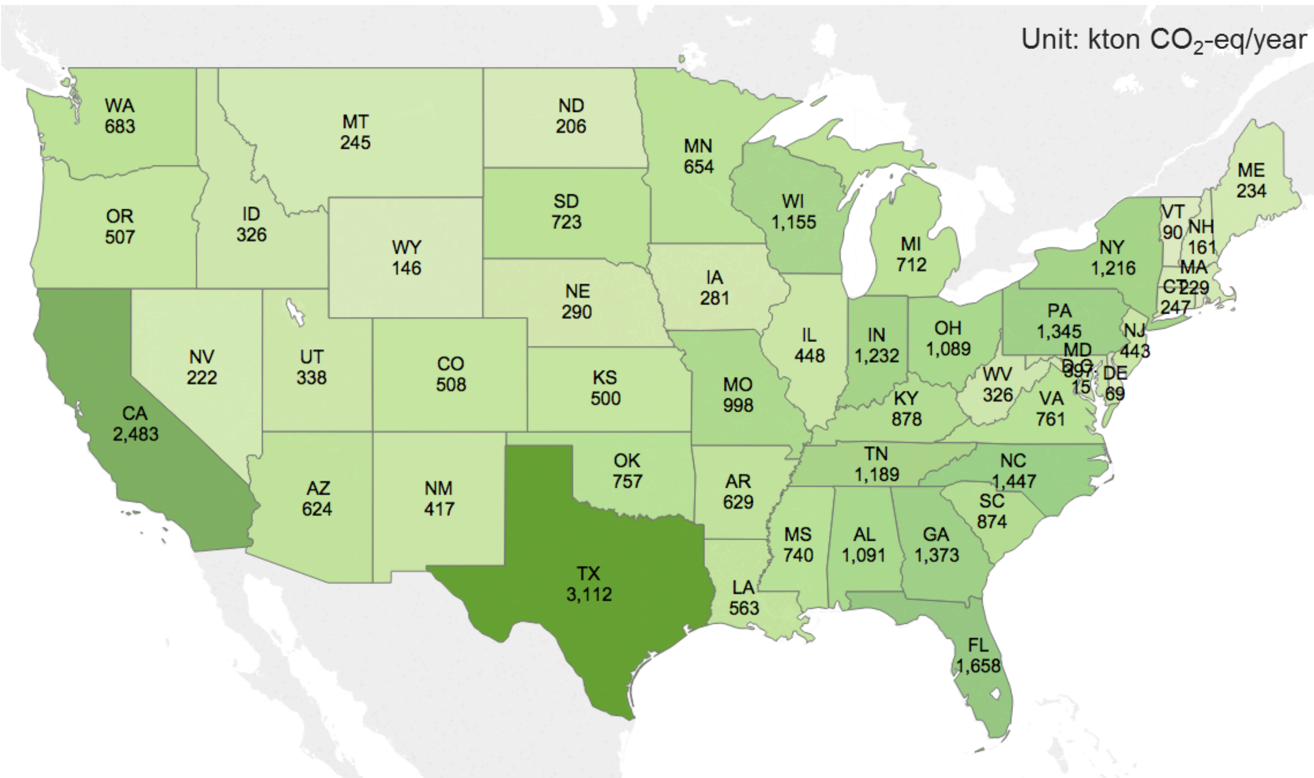

Figure 1. Annual GWP savings (kton CO_2-eq) by state from RF due to an initial 0.2 albedo increase for all urban and rural roads across the U.S.

Reference

1. Li, Z. and Garand, L. Estimation of Surface Albedo from Space: A Parameterization for Global Application. *Journal of Geophysical Research*, Vol.99(D4), 1994. p.8335.

2. FHWA. Highway Statistics 2016: HM-60. *US Department of Transportation Federal Highway Administration*, , 2017. at <https://www.fhwa.dot.gov/policyinformation/statistics/2016/hm60.cfm>

3. US EPA. Greenhouse Gases Equivalencies Calculator - Calculations and References. , 2017. at <https://www.epa.gov/energy/greenhouse-gases-equivalencies-calculator-calculations-and-references>

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