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EVALUATION AND DEVELOPMENT OF TOOLS TO QUANTIFY THE IMPACTS OF ROADSIDE VEGETATION BARRIERS ON NEAR-ROAD AIR QUALITY

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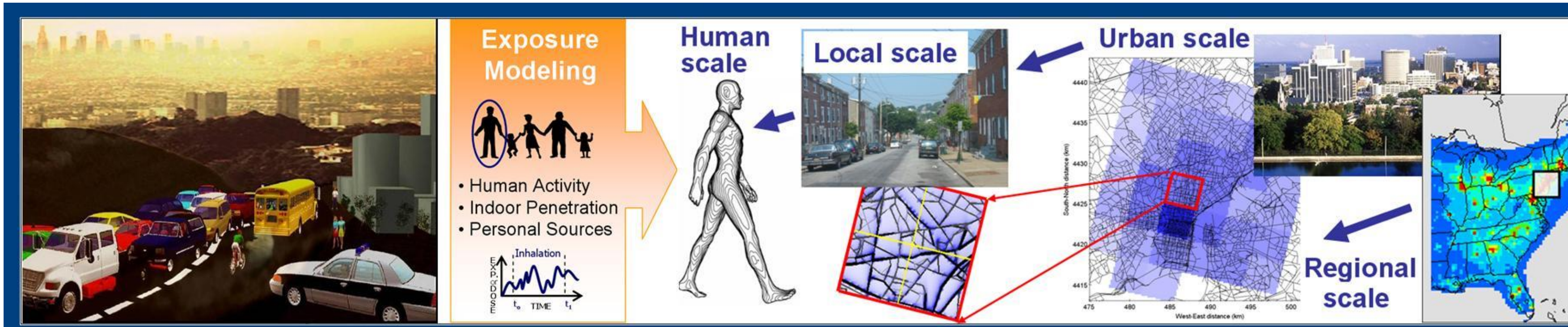

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Why study roadside vegetation?

- Few "short-term" mitigation options for near-road air quality concerns
  - ✓ Emission reductions take long to implement (fleet turnover required)
  - ✓ Planning and zoning involved in rerouting and traffic reduction programs
  - ✓ Buffer/exclusion zones may not be feasible or effective

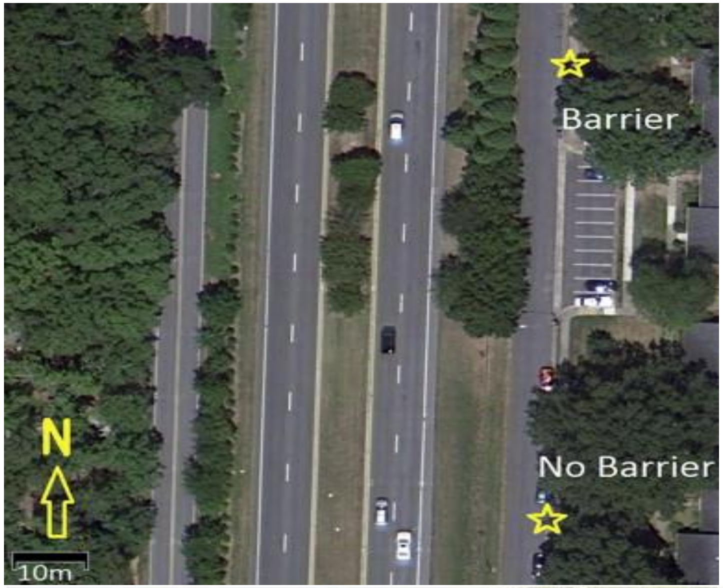
- Roadside vegetation may already be present

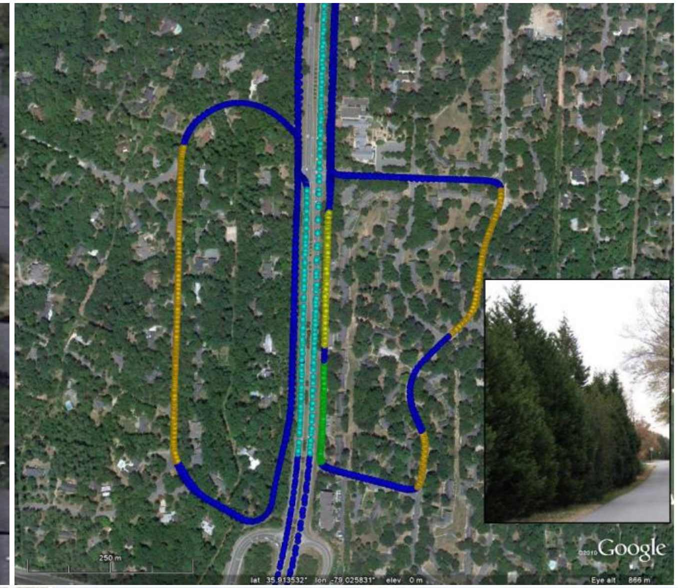
- Roadside vegetation has other positive benefits

Research Methodology

- EPA has initiated research to examine the role roadside vegetation may play in affecting near-road air pollution
  - ✓ Field studies
    - Chapel Hill, NC (vegetation)
    - San Francisco (vegetation)
  - ✓ Wind tunnel assessments
    - Site-specific configurations
  - ✓ Computational modeling
    - Comprehensive Turbulent Aerosol Dynamics and Gas Chemistry (CTAG) model with LES
    - Generalized vegetative scenarios

Chapel Hill Vegetation Barrier Study





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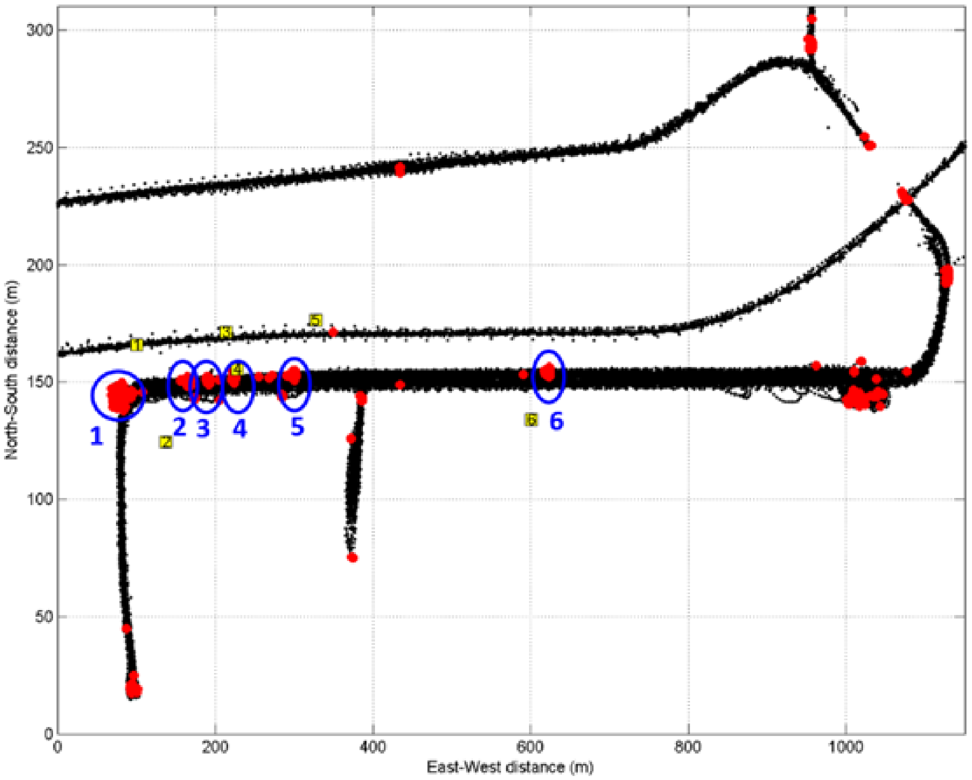
Chapel Hill Vegetation Barrier Study

- Used CTAG model with LES to simulate the impacts of vegetation barriers barriers
  - ✓ Evaluated model results against the Chapel Hill field study data[1]
  - ✓ The results of model evaluation against the Chapel Hill data provided us with the confidence in CTAG with LES to simulate other scenario
- Next, we used the model to explore the effects of vegetation barriers on near-road particle concentrations using various common near-road configurations
- Modeling suggests two potentially viable design options as a potential mitigation option for near-road particulates:
  - ✓ A wide vegetation barrier with high Leaf Area Density
  - ✓ Vegetation–solid barrier combinations, i.e., planting trees next to a solid barrier

[1]Tong et al., 2016, *Science Tot. Environ.*, **541**, 920-927

San Francisco Vegetation Barrier Study

- On-road and near-road mobile and fixed monitoring with varying vegetation types
  - ✓ Bush/tree combinations with varying porosity



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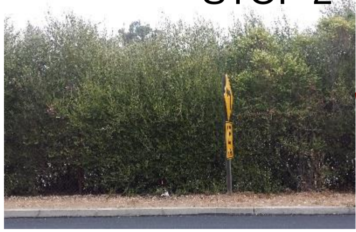
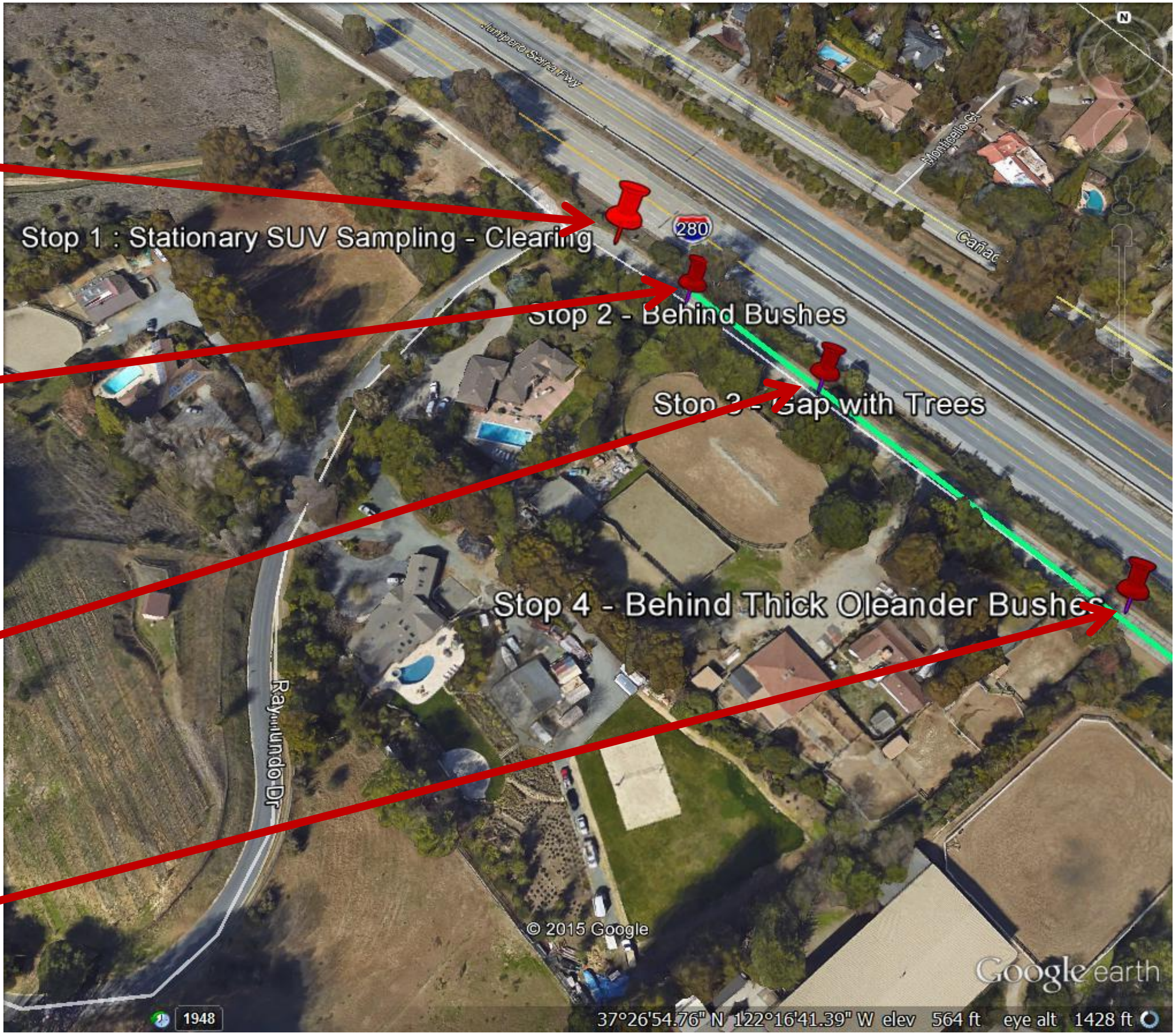
San Francisco Vegetation Barrier Study

STOP 2



STOP 3

STOP 4



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San Francisco Vegetation Barrier Study

Stop 1 – Clearing

Stop 2 – Thick Bush

Stop 3– Gap with Trees

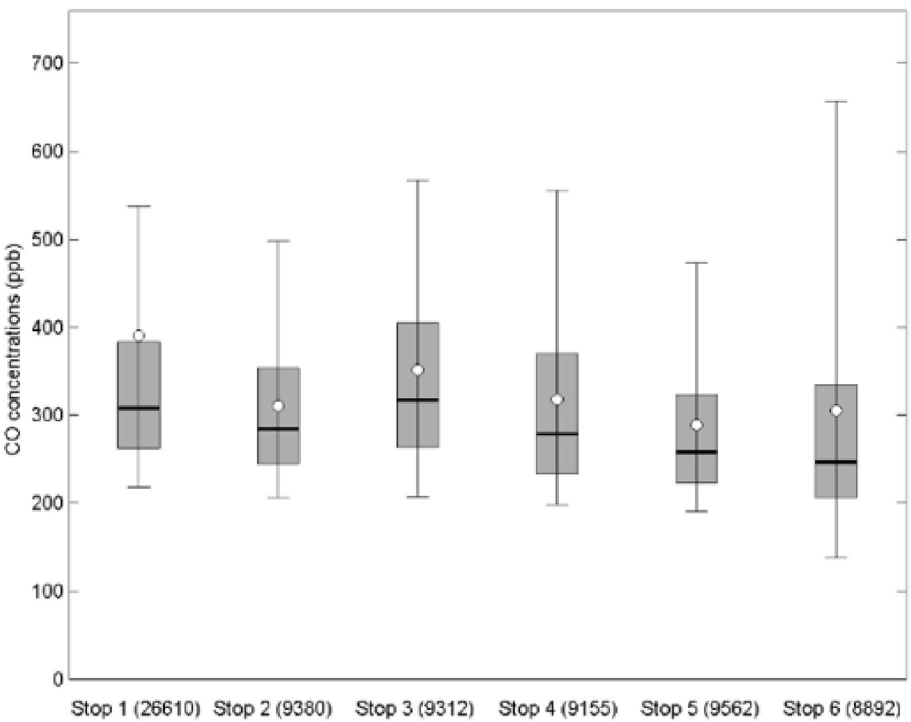
Stop 4 – Thick Oleander Bushes

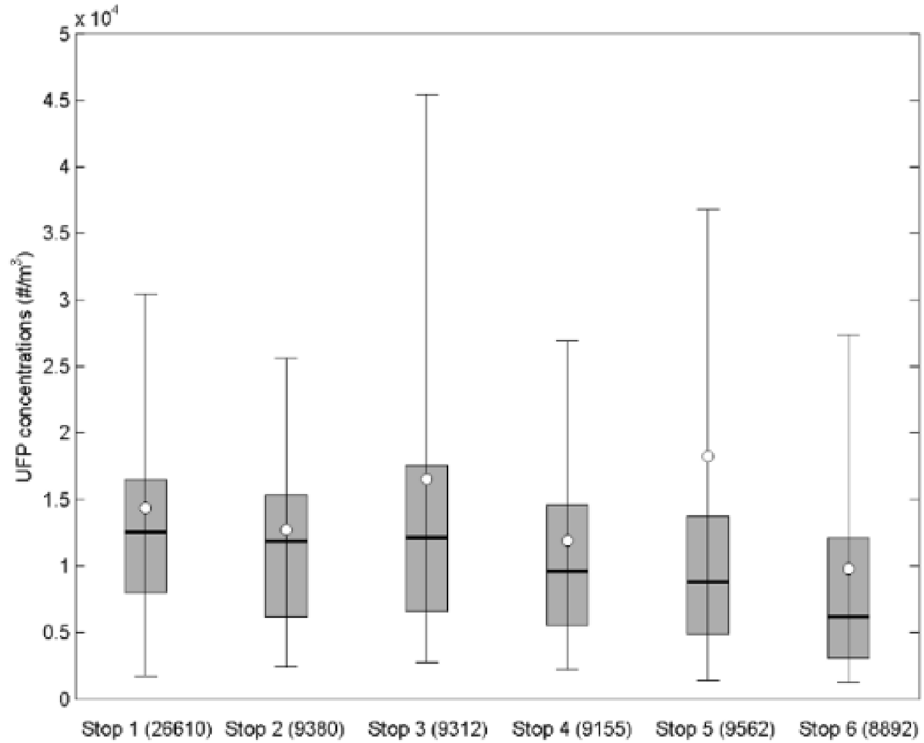
Stop 5 – Bushes, Trees with Gap

Stop 6 – Thick Bushes with Trees

San Francisco Vegetation Barrier Study

Distributions of observed CO and UFP concentrations from all 1-second mobile measurements in Woodside across six locations behind the barrier





- ✓ Each distribution is based on a roughly ten thousand observations during the entire field campaign.
- ✓ Thus, the distributions represent a longer-term exposure over the range of varying meteorological conditions

Modeling the Impact of Vegetation Barriers

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- We can quantify the effect of vegetation on reducing near road concentrations by estimating the height of a solid barrier that would resulted in the same reduction

- The primary effect of a solid barrier is to increase vertical dispersion of the pollutants emitted from the road

- A simple model of this effect adds the height of the barrier to the vertical dispersion

$$C = \sqrt{\frac{2}{\pi}} \frac{q}{W\sigma_w} \ln\left(1 + \frac{W}{d + \frac{HU}{\sigma_w}}\right) \qquad H = \frac{\sigma_w}{U}\left(\frac{W}{p-1} - d\right) \qquad p = \left(1 + \frac{W}{d + \frac{H_0 U}{\sigma_w}}\right)^R$$

where q is the emission rate per unit length of the road, H is the height of the barrier, σ_w is the standard deviation of the vertical velocity fluctuations, U is the near surface wind speed, R is the ratio of the concentration behind the vegetative barrier to the concentration in the open section, and H_0=2 m corresponds to vehicle induced turbulence in the open section

Effect of Vegetative Barriers on Concentrations

Stop Number	Height of Vegetation (m)	Description	Reduction *R*	Equivalent Barrier Height (m)
1	0	Clear	1	2.0
2	3-4	vegetation buffer ~6-7m with approx. 75% coverage	0.77	3.5
3	3-4	Wide gap (>4m) with highly porous mix of trees and thin bushes (~6-7m with approx. 50% coverage)	1	2.0
4	3-4	vegetation buffer ~6-7m with approx. 90% coverage	0.73	3.9
5	3-4	trees ~10m, thick vegetation buffer ~7m, and 1m wide gap with little vegetation	0.85	2.8
6	3-4	trees 10-12m, vegetation buffer ~7m with approx. 90% coverage	0.71	4.1

R refers to the mean of the reductions of the four species (CO, NO_2, BC, UFP) at each of the stops

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Summary – Vegetation Barriers

- Research shows the ability for roadside vegetation to reduce downwind pollutant concentrations near roads
- Design considerations are very important
- Vegetation should be appropriate for the location of use
- Best practice guidance and case studies needed to fully evaluate potential effectiveness of roadside vegetation and avoid unintended consequences
- Models will be important in designing and evaluating vegetative barriers
  - ✓ Simple model that adds the height of the barrier to the vertical dispersion
  - ✓ San Francisco study results show that computed heights are consistent with the heights of the vegetation
  - ✓ This suggests that it might be possible to estimate the equivalent height of a barrier using the actual height of the vegetative barrier and its porosity

Summary – Vegetation Barriers

- Areas desired for reduced concentrations should avoid gaps and edge effects
  - ✓ Vegetation barrier should provide coverage from the ground to the top of canopy
  - ✓ Barrier thickness should be adequate for complete coverage so gaps are avoided
- Pine/coniferous trees and thick bushes may be a good choice
  - ✓ No seasonal effects
  - ✓ Complex, rough, waxy surfaces

Summary – Vegetation Barriers

- Pollutants can meander around edges or through gaps
- Barrier thickness should be adequate for complete coverage to avoid gaps
  - ✓ No spaces between or under trees
  - ✓ No gaps from dead or dying vegetation; maintenance important

Summary - Vegetation Barriers

Combination of noise and vegetative barriers may provide most benefit

- Increase potential for pollutant dispersion and removal
- May be solid barrier with vegetation behind and/or in front
- Use of climbing vegetation and hedges with solid barrier may also provide additional benefits
  - ✓ Field study results mixed
  - ✓ Existing Vegetation on solid wall should extend enough to allow air to flow through