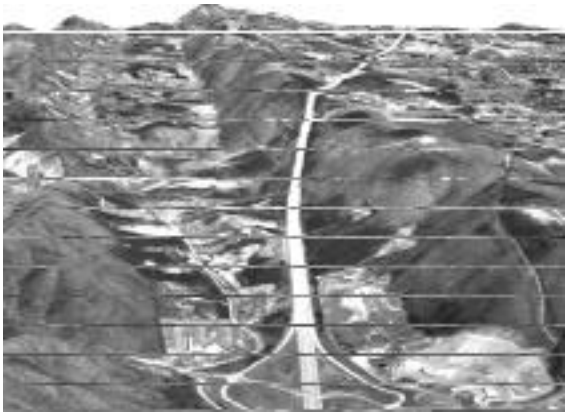
An ORNL State Partnerships Program Success Story

On-Road Emissions Measurement and Environmental Assessment Field Site

Stringent emissions standards for heavy-duty trucks will be imposed in the next few years, and research is needed to assess how the standards will affect air quality. However, there is a lack of accurate data to generate computer models to predict the impact of the standards because interactions among vehicle emissions and ambient air are not well understood. Laboratory tests are inadequate to predict emissions under actual driving conditions, and existing instruments for measuring on-road emissions are limited to single-vehicle or spot measurements. What is known is that heavy trucks are an important piece of the puzzle: over 40% of oxides of nitrogen (NO_x) and 50% of particulate matter (PM) emissions from mobile sources in the United States are from diesel engines, mainly from large trucks.

To address the data gap, ORNL and the University of Tennessee (UT) are creating a unique instrumented facility in East Tennessee to measure vehicle emissions in the real world of interstate traffic. The proposed research site is a 2.5-mile stretch of Interstate 40 east and west of the Watt Road interchange west of Knoxville, Tennessee. The interchange is home to several large truck stops, a freight distribution center, and service facilities that attract 18-wheelers. Some 10,000 to 12,000 trucks drive the stretch daily, and at any given time, hundreds of idling big rigs fill the truck stop lots as drivers pull over to sleep for a few hours.

Contributing to the uniqueness of the study area is the bowl-shaped topography around the interchange, which sits in a valley between high ridges. Emissions are trapped under conditions ideal for the study of ambient air chemistry and the atmospheric diffusion of compounds in vehicle exhaust. In addition, trucks traveling east from the interchange must climb a steep grade, resulting in heavy emissions of particulate matter (PM) and oxides of nitrogen.



A simulation of the topography surrounding the Watt Road interchange. The interchange is at the bottom of the figure.

The goal of the ORNL/UT project is to establish a field laboratory devoted to

- Studying in-use, real-world emissions of heavy trucks
- Studying the impact of emissions reduction technologies for heavy trucks
- Developing instrumentation for remote sensing and analysis of truck emissions
- Enhancing the understanding of how vehicle emissions interact with ambient air quality

To characterize the study area and determine the best locations for instrumentation, an array of meteorological data (e.g., wind direction, speed, and

fluctuation), detailed traffic data, and updated digital aerial imagery of the site are needed. The ORNL State Partnerships Program provided support for a site survey to supply this basic information and for information meetings with participants and stakeholders (including local, state, and federal agencies) and potential research sponsors. The site survey has been completed, locations for meteorological monitoring stations established, and provisional permission obtained from state agencies to install instruments on the right-of-way.

ORNL is providing Laboratory-Directed Research and Development (LDRD) funds to develop prototype instruments that will remotely and non-intrusively measure NO_x and PM (soot) emissions from trucks as they as they pass a point in the I-40/Watt Road corridor. (ORNL has extensive expertise in developing instrumentation to measure and characterize engine emissions, and unique equipment and facilities dedicated to emissions research.) These instruments will use optical techniques to pass beams across the roadbed, intercept the truck's exhaust plume, and deliver signals that indicate the concentrations of the emissions of interest back to receptors. The techniques will be non-intrusive to the point that the driver likely will not know that his truck's emissions are being sampled. A LIDAR (light detection and ranging) technique will be used to acquire data on particle density, and an ultraviolet absorption technique will yield data on NO_x.

It is not enough, though, to measure just the emissions concentrations. It is necessary to know in what mode the engine is operating, for example, its engine speed, turbine speed, and number of cylinders. In a laboratory setting, these data would be easily obtained; but acquiring the information from a moving truck, with a driver who is not participating in the research, is a daunting task. For this task, the ORNL researchers will apply a sound signature analysis technique to gather information about the engine operation. The sound of the truck's passing will be recorded at the same time that the emissions are being measured. Analyzing and de-convoluting the sound signal will yield the desired data about the engine—including engine speed, number of cylinders, and turbine speed—allowing the emissions to be calculated to a gram-per-mile basis, which is the desired format for the information.

Once the emissions monitoring stations are installed, the ambient air quality and emissions readings supplied by the instruments will provide data to improve computer models predicting how various operating conditions for vehicles (e.g., use of alternative fuels, use of emissions control devices) will affect air quality.

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