September 5, 2012 - Presentation to Duke University's WISeNet Program

Emerging research on real-time air pollution sensing with the US EPA, Office of Research and Development

Office of Research and Development
National Risk Management Research Laboratory/Air Pollution Prevention and Control Division

Overview

- Introduction
- Background on air quality science
- Specific research projects / researchers at EPA:
    - Brian Gullett
    - Eben Thoma
    - Ram Vedantham
    - Gayle Hagler

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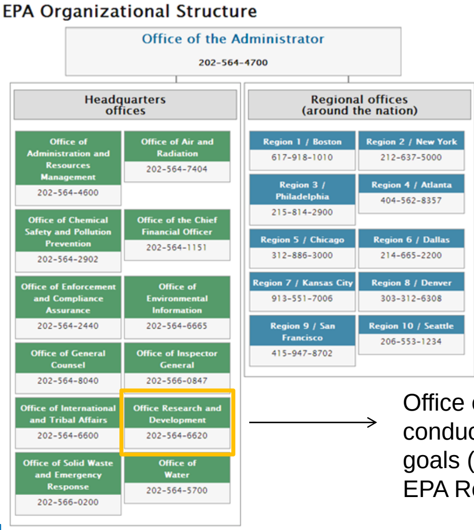
Introduction to EPA ORD

EPA Organizational Structure



Office of Research and Development: conducts research to support Agency goals (improved regulations, support to EPA Regions, etc.)

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Introduction to EPA ORD

EPA's location in Research Triangle Park, NC (off of TW Alexander Drive)
- Major center for air pollution research and regulation (Office of Research and Development, Office of Air Quality Planning and Standards)
- Laboratory facilities, high performance computing support, meeting space, offices
- On-site air monitoring station, source testing facilities (dynamometer, high bay)

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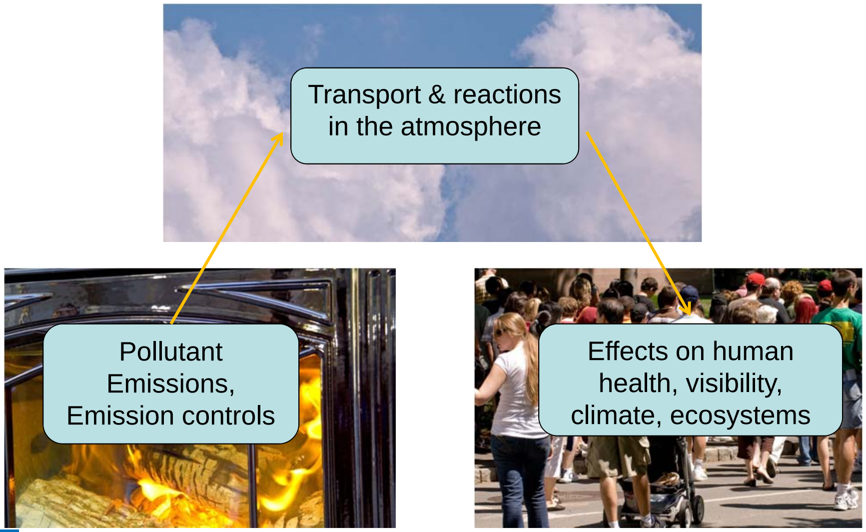
Air Quality Research



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Air Quality Research

Characterize Emissions (anthropogenic and biogenic)

ORD research questions:
- Which pollutants?
- What are the emission rates?
- What are ways to improve emissions?

Particular challenges:
- Area sources
- Fugitive emissions
- Difficult to replicate in a laboratory setting (e.g., wildfires)

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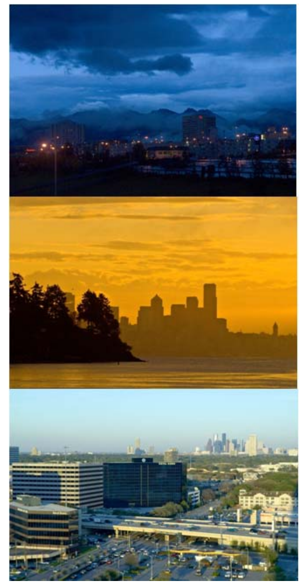
Air Quality Research

Understand transport & reactions in the atmosphere



ORD research questions:

- What is the atmospheric lifetime of pollutants? (Seconds? Minutes? Weeks? Years?)
- How do pollutants disperse and affect very local (10s of meters) to regional-scale (100s of km) to global-scale (1000s of km) air quality?
- How do pollutants form or transform after emissions and what drives the changes? (e.g., ozone, secondary particles)
- How are pollutants removed from the atmosphere?

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Air Quality Research

Evaluate effects on human health, visibility, climate, ecosystems

ORD research questions:

- What are the health effects of “fresh” and “aged” pollutant emissions; what is the mechanism of injury?
- Does living in close proximity to a certain source or sources increase risk of developing health conditions?
- How does short-term versus chronic exposure relate to health impacts?
- What are the climate and visibility impacts?
- Are ecosystems damaged by air pollution?
- Are certain populations disproportionately affected (environmental justice)?

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Air Quality Research

Focus of most of the research presented today:

Transport & reactions in the atmosphere

↑

Pollutant Emissions

Brian Gullett, PhD – gullett.brian@epa.gov
- Aerial source sampling

Eben Thoma, PhD – thoma.eben@epa.gov
- Assessing fugitive and area sources

Ram Vedantham, PhD – vedantham.ram@epa.gov
- Hybrid model-measurement strategies to detect sources

Gayle Hagler, PhD – hagler.gayle@epa.gov
- Assessing spatiotemporal variability in local air quality

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Aerial source sampling - Brian Gullett

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Aerial source sampling -- Brian Gullett

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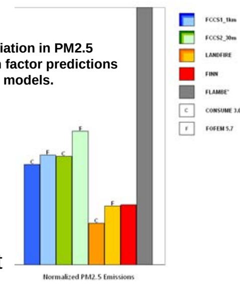
1/3 of all respirable $PM_{2.5}$ is from forest fires

Motivation:

Open area pollution sources contribute significantly to the global pollution budget. Yet they are difficult to safely, representatively, and accurately sample. This is particularly true for thermally-lofted plumes. As such, quantitation is uncertain, with a factor of 2-6x variance. Related impacts include ambient air quality, traffic safety, near-source exposure, global climate effects.

Wide variation in PM2.5 emission factor predictions amongst models.



Research Questions:

What are the emission factors (mass of pollutant/unit of activity, e.g., mass of CO/hectare of forest burned) from these sources?

How well can we predict the downwind concentrations and exposures with dispersion models.

Research Approach:

Development of lightweight, aerial- and ground-based measurement systems.

Field measurements of concentrations.

Dispersion modelling.

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Aerial source sampling -- Brian Gullett

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Development of "lightweight", balloon-loftable sampler.

Prescribed forest burns, USMCB Camp Lejeune

Open burning of Sparrow rocket motor propellant, Tooele Army Depot.

Open waste burns, military burn pits.

In situ oil burns, Deep Well Horizon, Gulf of Mexico.

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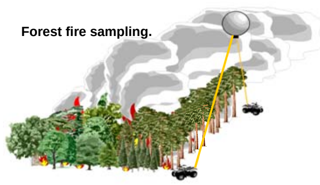
Open detonations of military ordnance, Tooele Army Depot.

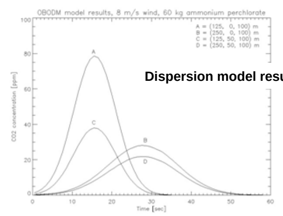
Aerial source sampling – Brian Gullett

Sensor networks necessary for
- **downwind positioning of aerostat**
- **plume dispersion mapping**
- **human exposure monitoring.**

Forest fire sampling.



Simulation of military forward operating base.



Dispersion model results.

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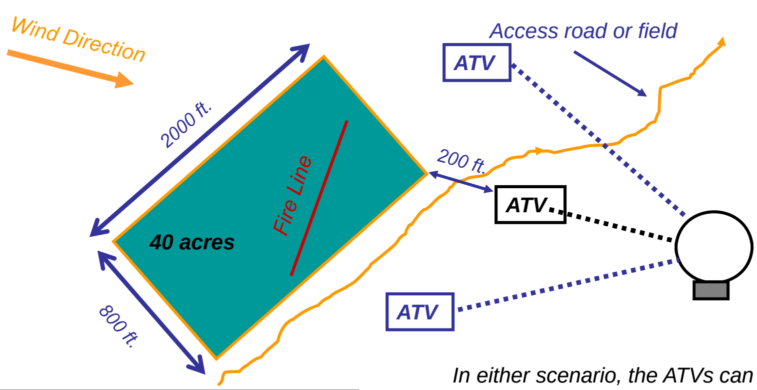
Anticipated burn sampling scenarios



(dotted lines)	*Tethers*
ATV	*Single tether scenario*
ATV	*Double tether scenario*

In either scenario, the ATVs can be repositioned during or between the burns. In lighter winds with a strong plume loft, the ATVs would be moved more to a flanking position, with the Flyer above the field.

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Assessing fugitive and area source emissions
- Eben Thoma

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Mobile measurements for assessment fugitive and area sources – Eben Thoma

Motivation:

Fugitive and area source emissions are hard to measure sometimes hard to even find. For oil and gas production operations, potential sources can be spread out over large areas. For sources such as landfills and industrial facilities emissions , emissions are heterogeneous and can occur over a large area.

Research Questions:

How can we better understand air emissions from distributed point sources large area sources like landfills?

Research Approach:

Develop and use special optical remote sensing , mobile measurements, and network approaches to find and assess emissions

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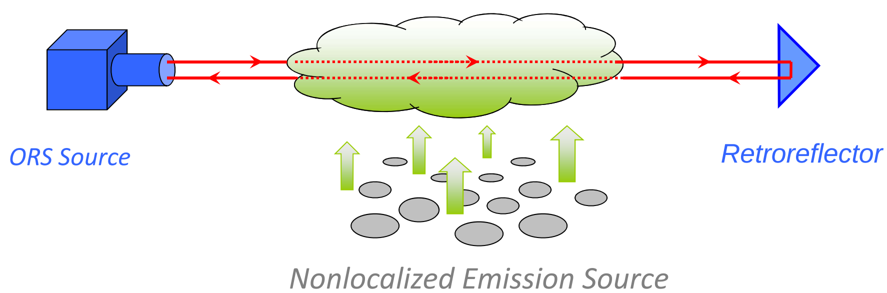
Fugitives emissions and area sources

<u>*Difficult to assess:*</u>

- *Extended area*
- *Spatially complex*
- *Temporally variable*

Optical Remote Sensing (ORS)

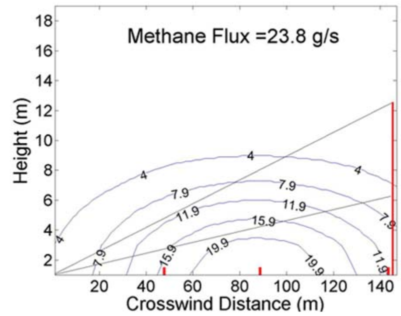


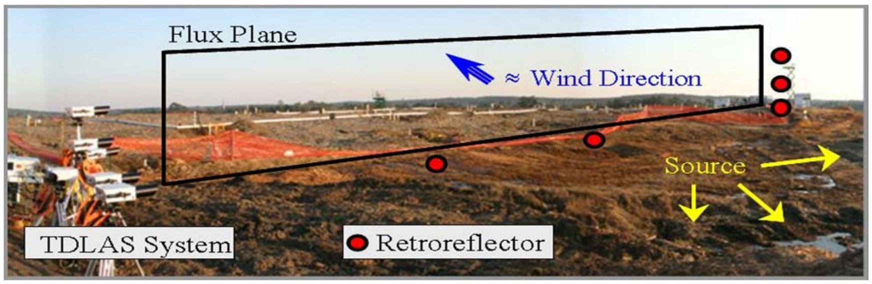
Open-path instruments provide path-averaged concentration data

Landfill Bioreactor Emissions

(using tunable diode laser flux plane)

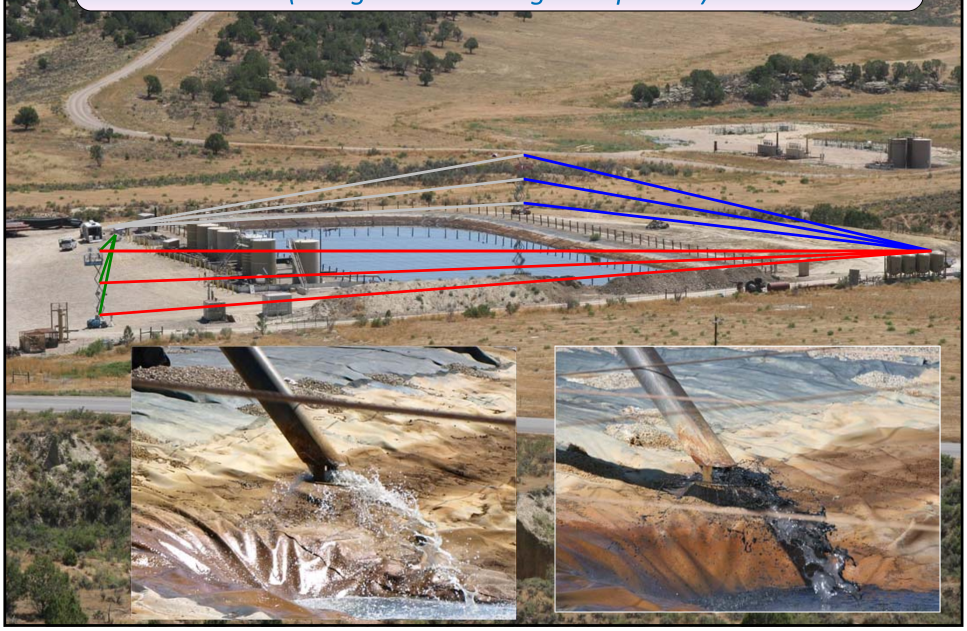
- *Experimental Bioreactor Cell*
- *Air and leachate injection*
- *Open wells on side slope*



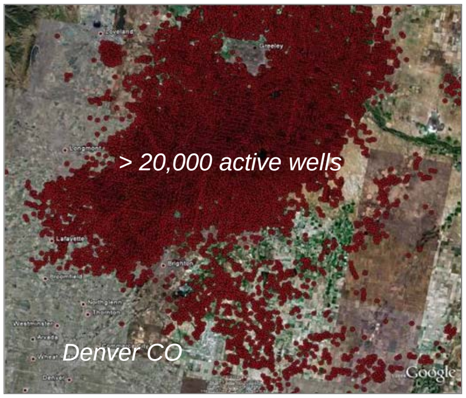


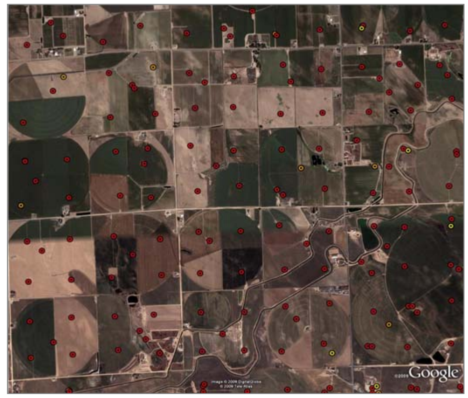
VOC emissions from oil and gas produced water pond

(using two scanning FTIR planes)



Oil and gas production
(large number of potential sources)





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When people live in very close proximity to potential emissions, the need for periodic inspection increases

Source: Microsoft Bing Maps (© Microsoft Corporation Pictometry Bird's Eye © 2010 Pictometry International Corp)

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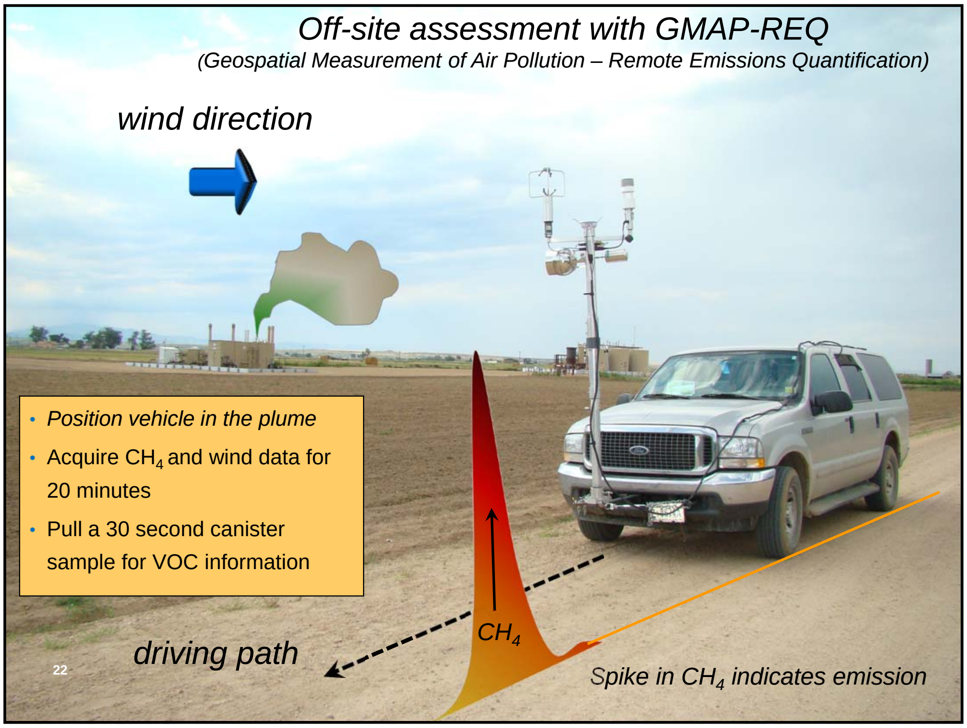
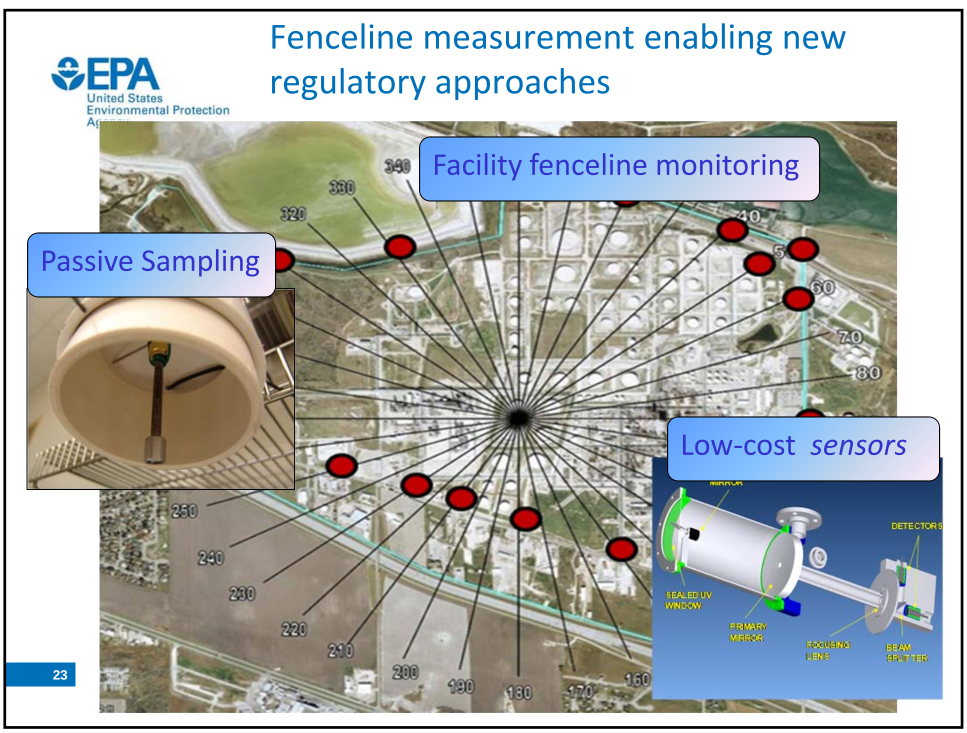

Off-site assessment with GMAP-REQ
(Geospatial Measurement of Air Pollution – Remote Emissions Quantification)
wind direction
Position vehicle in the plume
Acquire CH_4 and wind data for 20 minutes
Pull a 30 second canister sample for VOC information
CH_4
driving path
22
Spike in CH_4 indicates emission


EPA
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Fenceline measurement enabling new regulatory approaches
Facility fenceline monitoring
Passive Sampling
Low-cost sensors
340
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Hybrid model-measurement strategies to detect sources - Ram Vedantham

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Isolating pollution sources from real-time air monitoring data – Vedantham

<u>Motivation</u>:

In order to improve air quality, understanding the actual contribution of sources is key. Mathematical models utilizing field data are one approach to provide source contribution estimates, grounded by field observations.

<u>Research Questions</u>:

How can we maximize source information derived from continuous, high time resolution field measurements of air pollution and meteorology?
How can we utilize signal processing principles to interpret air monitoring time series?
How can we optimize future field measurement campaigns to strengthen source information?

<u>Research Approach</u>:

- Analysis of existing near-source field data sets
- Planning and implementing field studies
- Publishing tools for public use

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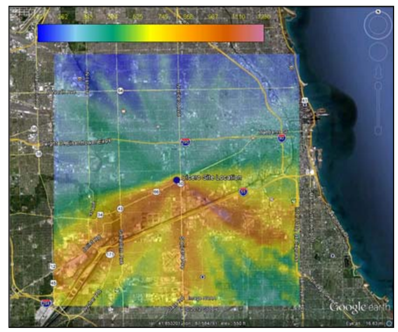
Isolating pollution sources from real-time air monitoring data – Vedantham

Hybrid model+point measurements to identify source impacts

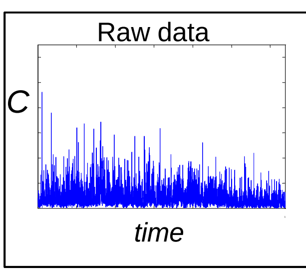
Near real-time (1-5 min) measurements
+
Inverse wind trajectory modeling
=
Estimated source contribution zones



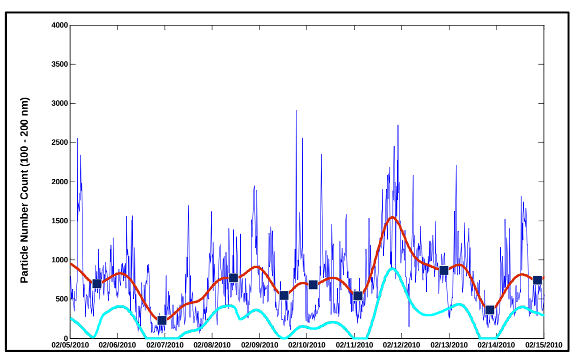
e.g., model output for a recent rail yard study (Rizzo et al.) →

Isolating pollution sources from real-time air monitoring data – Vedantham

Estimating local and regional contributing factors



Fast fourier transform (FFT) analysis – signal deconvolution, rebuild of "regional" type factors from slow-varying components



Estimating slow-varying ("regional") and fast-varying ("local sources") signals →

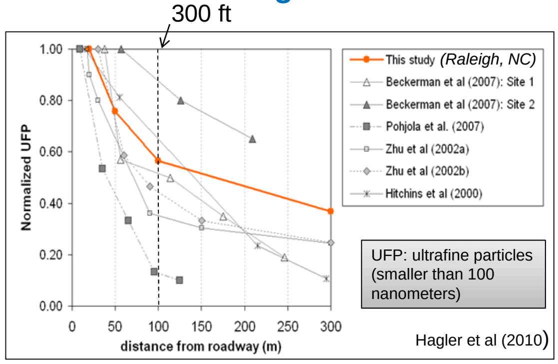
Assessing spatiotemporal variability in local air quality - Gayle Hagler

Studying the air pollution trends nearby major transportation sources – Hagler

Motivation:

Over 45 million people in the US estimated to live within 300 feet of a major transportation system.

Major challenge to develop field data at a spatial, temporal, and pollutant-specific resolution sufficient to resolve trends. →



Hagler et al (2010)

Research Questions:

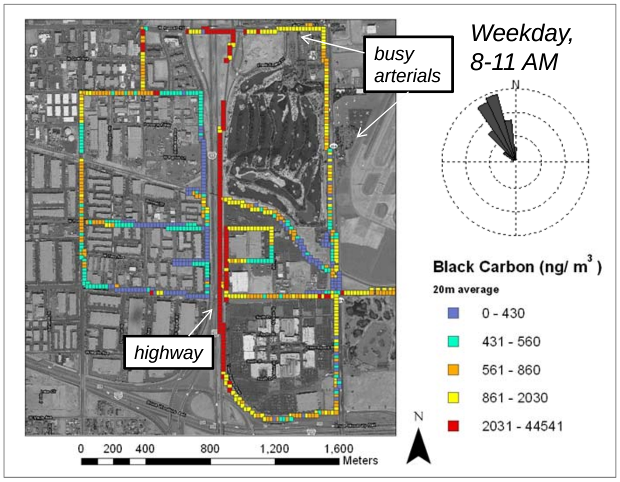
- What is the spatiotemporal variability of air pollution nearby major sources?
- What strategies can be employed to reduce air pollution exposure?
- How can we measure air pollution at a higher spatial resolution and retain sufficient data quality to determine important trends?

Research Approach:

- Field measurement studies (long-term and short-term)
- Modeling (numerical, wind tunnel models)

Assessing spatiotemporal variability in local air quality – Hagler

Mobile mapping of air quality (e.g. Las Vegas)

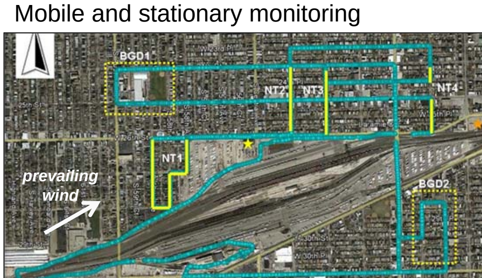


- Multipollutant, real-time (~1 s) sampling (carbon monoxide, black carbon, particulate count/size, nitrogen dioxide, carbon dioxide)
- Custom electric platform, 100 mile range
- Applied to highways, arterials, near-rail yard areas

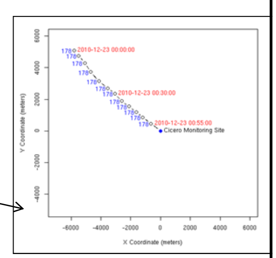
Assessing spatiotemporal variability in local air quality – Hagler

Multi-pronged approach to understand complex near-source environments….

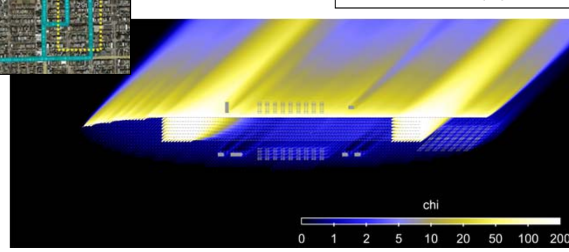
Mobile and stationary monitoring



Localized back-trajectory modeling (Rizzo et al.)



Computational fluid dynamics modeling



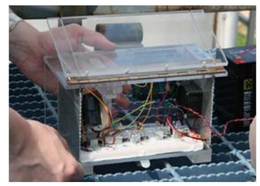
Assessing spatiotemporal variability in local air quality – Hagler

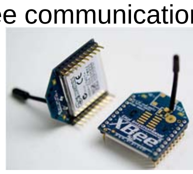
Developing/evaluating new measurement strategies

Village Green Project:
- Solar-powered air and meteorological sampler
- Lower cost, real-time instruments - proven capability at ambient levels (wind, black carbon, $PM_{2.5}$, ozone)
- Wireless data communication to website
- Designed for public environments
- Prototype under development (2013 installation)

Conceptual sketch

Exploring ultra-low cost air pollution sensing:
- Very low cost pollutant sensors (<$100)
- Arduino microprocessor – open source code
- Zigbee communication network w/ XBee modules





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Conclusions

- Significant interest in EPA ORD in air pollution sensor networks, from the point of new technology development to optimal application of sensors to maximizing information derived from sensor signals.

- We are very interested to learn about collaborative research with the WISeNet program

- Gayle Hagler will serve as primary point of contact for facilitating collaborations; Eben Thoma will be main point of contact during Oct-Dec 2012 timeframe

  Gayle: hagler.gayle@epa.gov, 919-541-2827
  Eben: thoma.eben@epa.gov, 919-541-7969

- Questions? Comments?

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Appendix

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