



ADDRESSING THE CHALLENGES OF BLACK CARBON IN RUSSIA

A Joint U.S. National Academies – Russian Academy of Sciences Workshop

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Overview of EPA activities and research related to black carbon

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Disclaimer: The views here represent those of the author and not necessarily of the United States Government



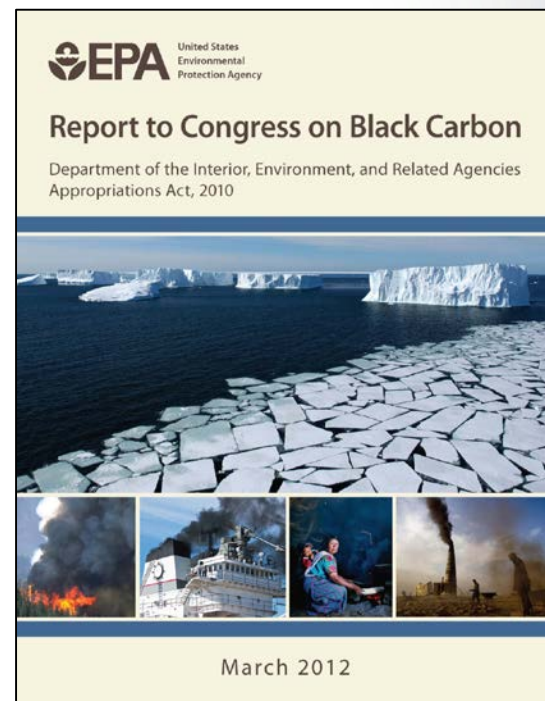
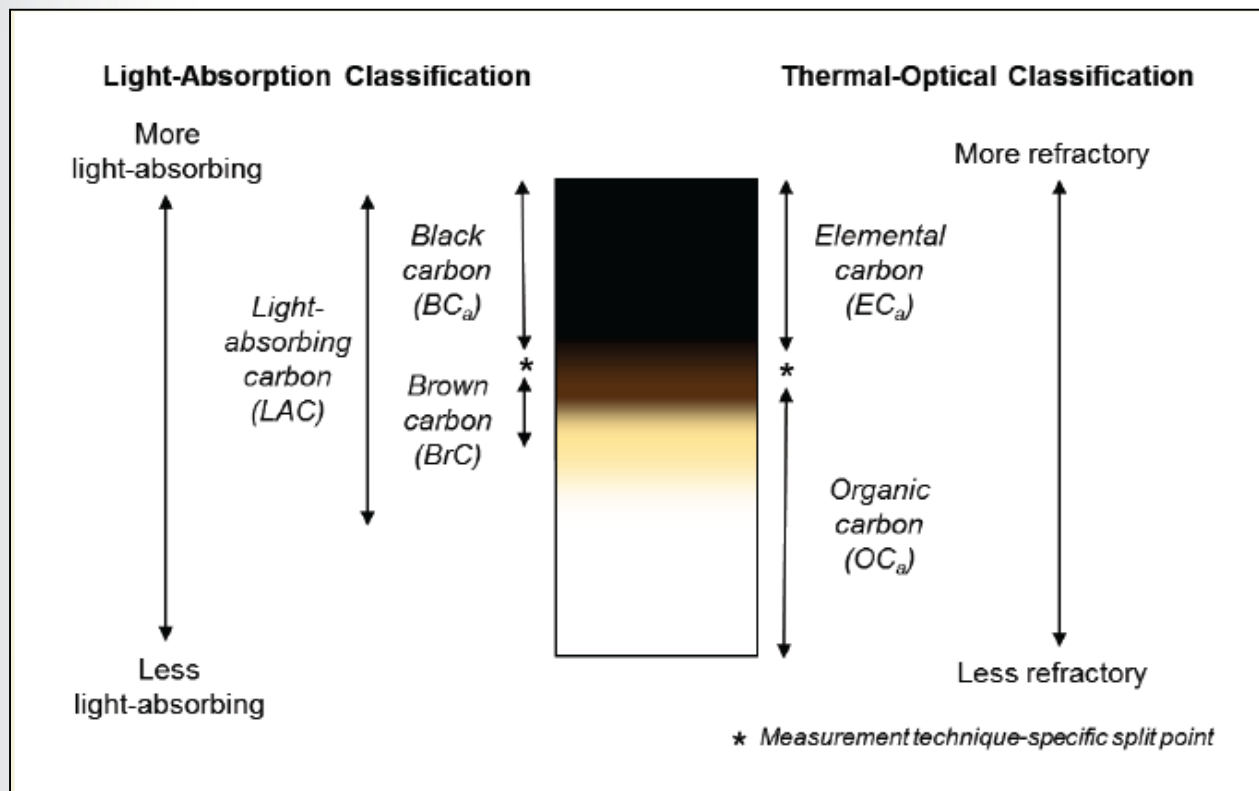
Purpose

The purpose of this international presentation is to give an overview of EPA activities related to black carbon (BC). This overview includes some summary information on how EPA defines BC, current knowledge on United States emissions and forecasted emission reductions, and ongoing research regarding measurement methodology, emissions characterization, and near-source research.



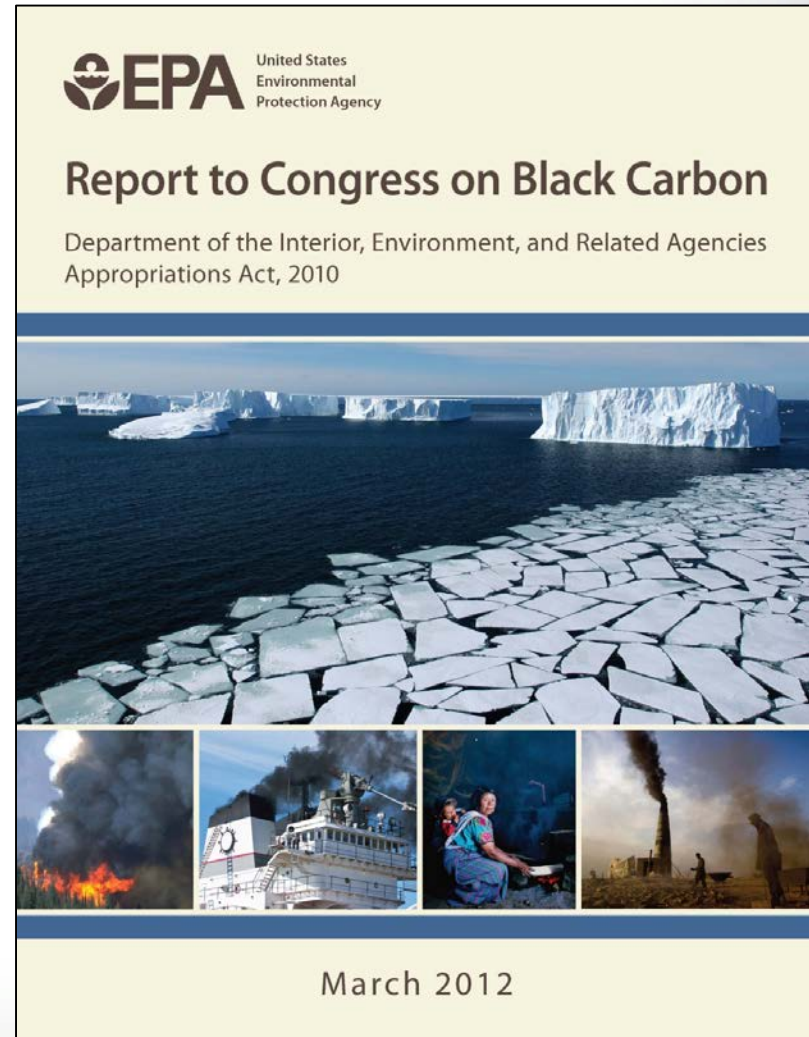
- US EPA interest in black carbon emissions and impacts
- Black carbon emissions in the United States – past and future
- Ongoing EPA research related to black carbon
 - Measurement methods
 - Emissions characterization
 - Near-source air quality impacts

Defining BC



“Black carbon (BC) is a solid form of mostly pure carbon that absorbs solid radiation (light) at all wavelengths. BC is the most effective form of PM, by mass, at absorbing solar energy, and is produced by incomplete combustion.”

- Health effects:
 - BC is an important component of $PM_{2.5}$
 - Indicator of localized air pollution impacts: elevated levels have been observed in close proximity to transportation sources
- Climate impacts
 - Direct effect through absorption of solar radiation in the air, or deposited to snow/ice
 - Indirect effect on cloud properties
 - Mitigation of BC as complementary and providing increased effectiveness, than reduction in CO_2 emissions alone, due to its short atmospheric residence time.



Climate effects of black carbon emissions

The impact of BC on snow and ice causes additional warming in the Arctic region and contributes to snow/ice melting.
VERY LIKELY BUT MAGNITUDE UNCERTAIN

BC in northern hemisphere mid-latitude snow leads to earlier springtime melt and reduces snow cover in some regions. **LIKELY BUT MAGNITUDE UNCERTAIN**

The warming caused by BC is concentrated in the northern hemisphere.
VERY LIKELY

Absorbing aerosols may have caused changes in precipitation patterns with largest effects likely to be in South Asia.

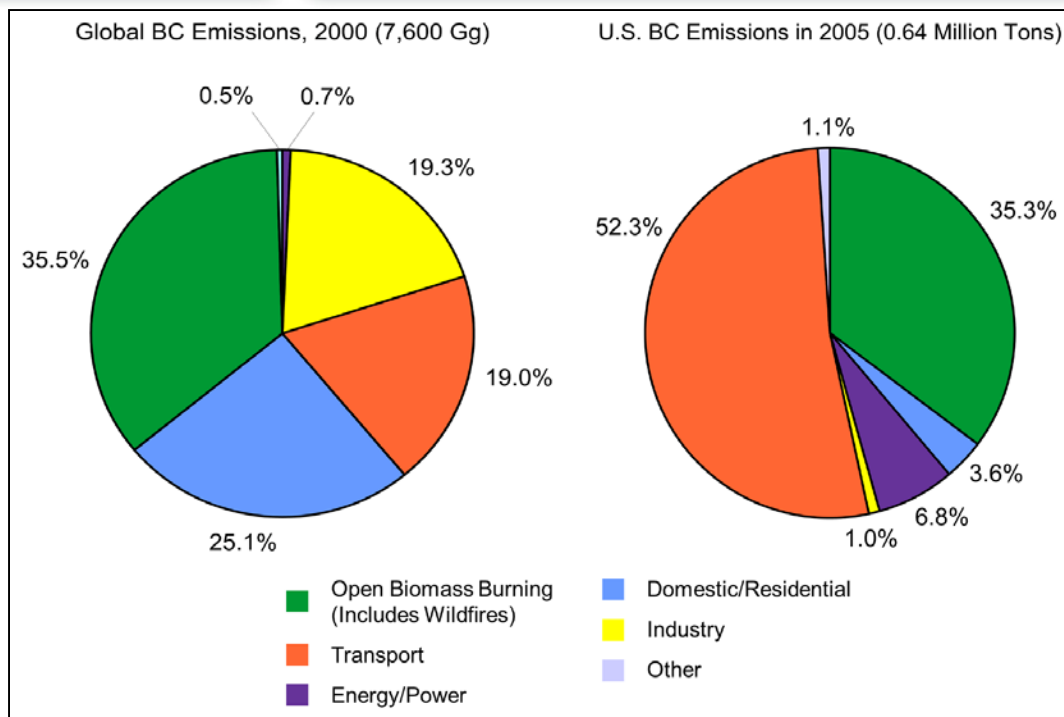
The hemispheric nature of the BC forcing causes a northward shift in the ITCZ.
LIKELY.

Absorbing aerosols may cause circulation changes over the Tibetan Plateau and darkening of the snow. The importance of this for glacier melting is unknown.

Source:
Bond et
al. (2013)



United States Emissions

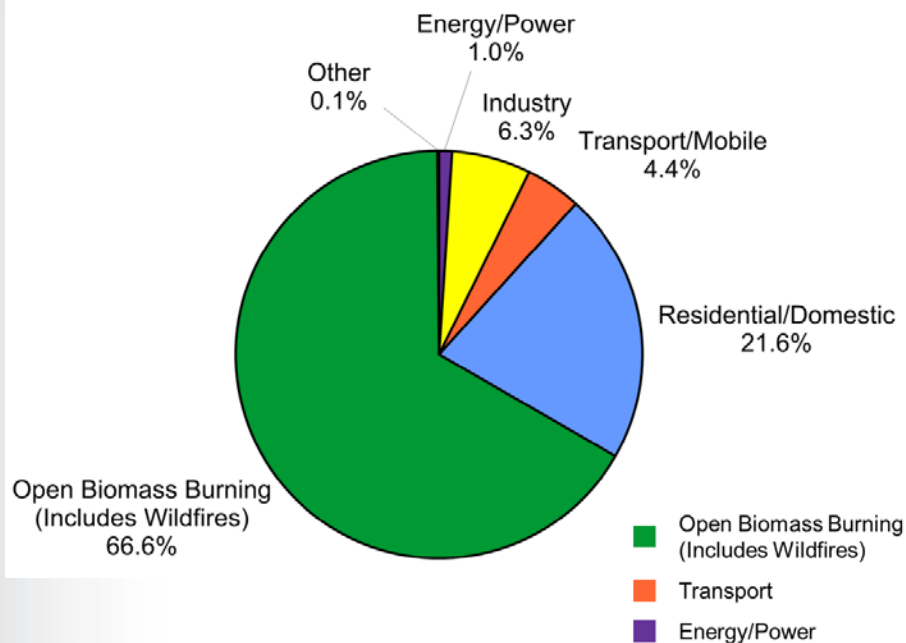


- In the US, there is estimated, in 2005, to be about 0.64 tons of BC emitted by all sources.
- Globally, about 8.4 million tons of BC is emitted.
- Distribution of sources in US is different than globally for BC.
- In the US, BC emissions, generally, are derived from PM_{2.5} emission inventories, via use of speciation factors.

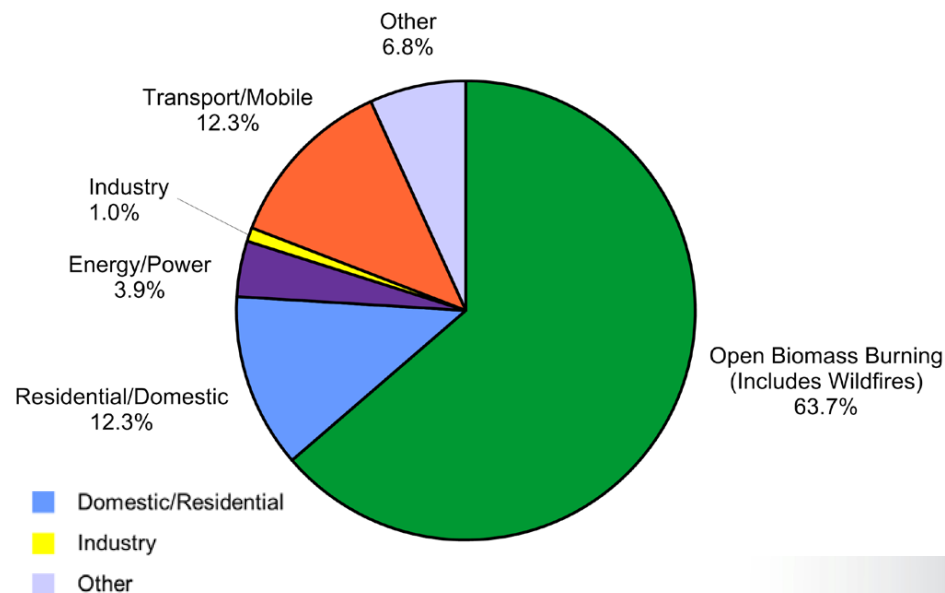


United States Emissions

Global OC Emissions, 2000 (35,700 Gg)



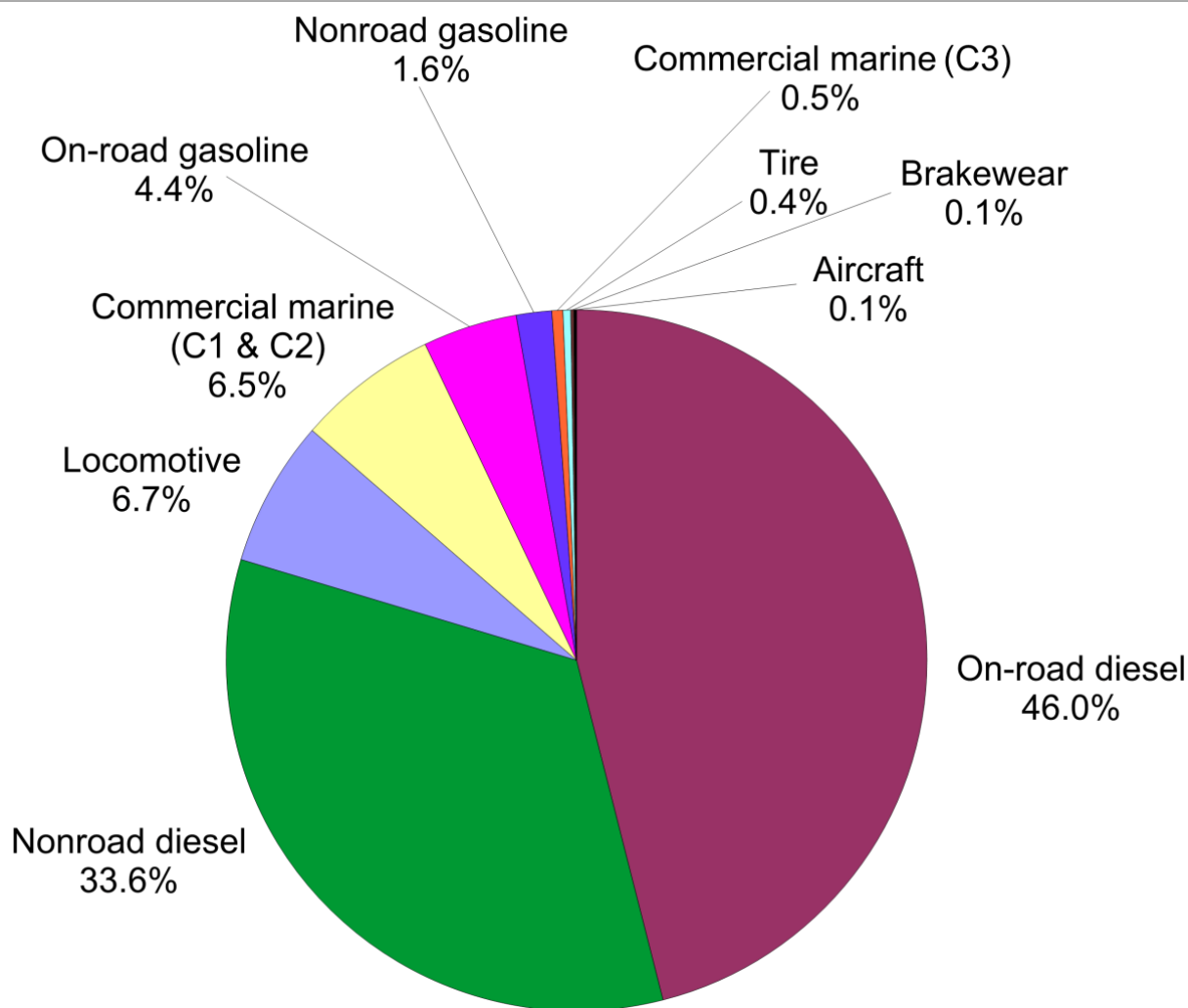
U.S. OC Emissions in 2005 (1.7 Million Tons)



- Organic carbon (OC) always co-emitted with BC, must be considered in any control and/or mitigation scenarios.
- Most of OC comes from open burning, and is considered to be reflective (cooling).
- How much of OC is light-absorbing (warming brown carbon, BrC)?



U.S. mobile sources



- U.S. mobile source BC comes mainly from diesels
- Gasoline exhaust is a smaller source of BC

U.S. Black Carbon Emissions from all Mobile Source Categories, 2005
(total 333,400 tons)



U.S. mobile sources

BC emissions from U.S. mobile sources controlled by:

- **Emissions standards** for new engines
 - Requirements for diesel particulate filters (DPFs) in conjunction with ultra low sulfur diesel (ULSD) fuel
 - Gasoline vehicle volatile organic compounds (VOCs, and other gaseous pollutants) standards also reduce PM emissions
 - Standards for PM are “technology forcing.”
 - Reductions estimated from emissions models used in regulations
 - On road BC, OC, PM inventory from MOVES (Motor Vehicle Emission Simulator) model
 - Nonroad BC inventory from NONROAD model
 - Locomotive, marine, and aircraft emissions estimated by separate models
- **Retrofit programs** for in-use mobile diesel engines, such as EPA’s National Clean Diesel Campaign and the SmartWay Transport Partnership Program

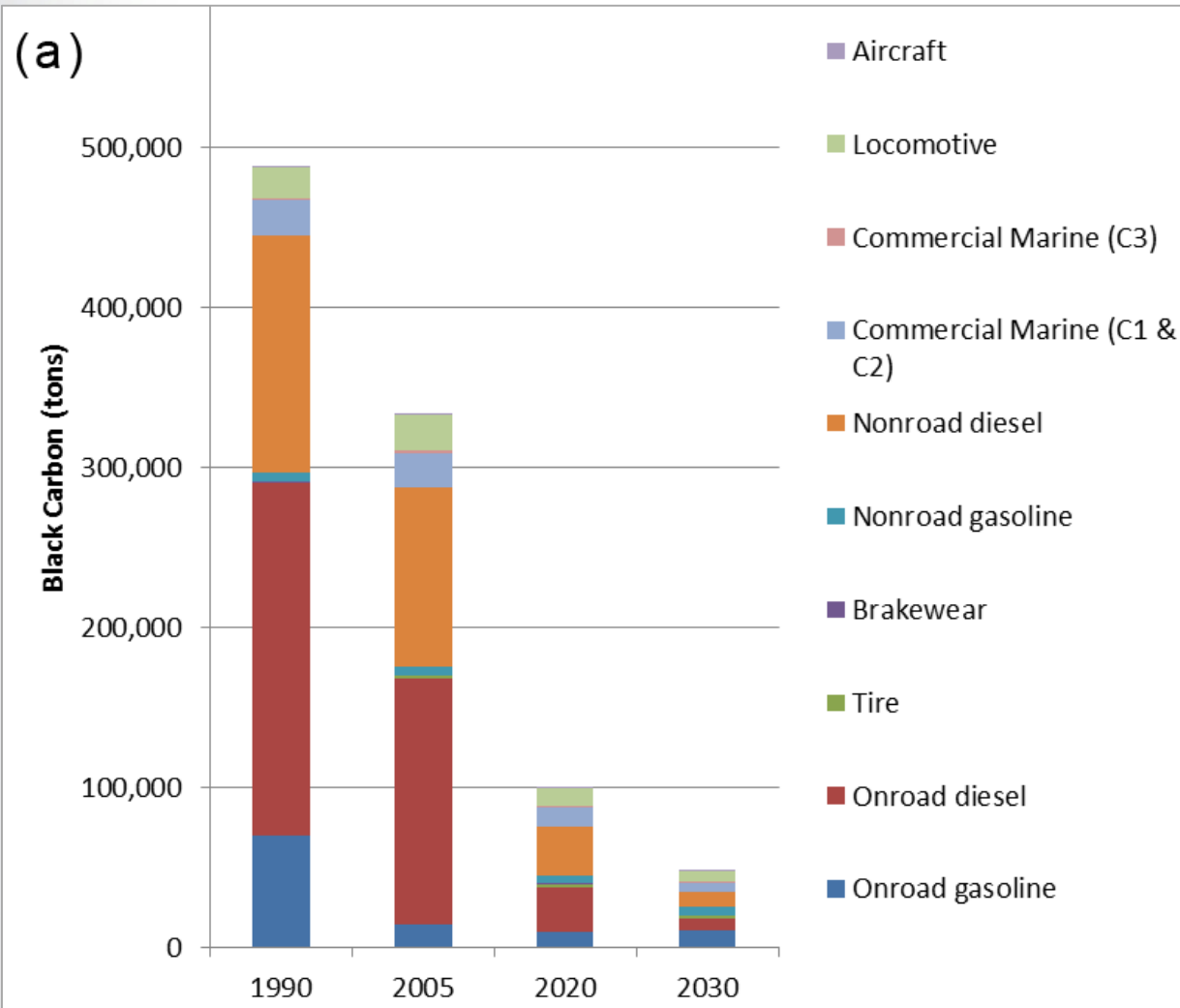


U.S. mobile sources

- On-road diesel PM standards – 2007 model year
 - 99% reduction in diesel PM for 2012 diesel trucks compared to 1970 pre-control diesel trucks
 - On-road diesel PM and BC reduced by 91% and 95% respectively from 2005-2030
 - Diesel particulate filters preferentially reduce BC
 - Earlier diesel PM standards also reduced BC
 - Fleet turnover needed to achieve full PM/BC reductions
- Standards for non-road diesels started in 2012
- Standards for locomotives and commercial marine (categories 1 and 2 but not ocean going)



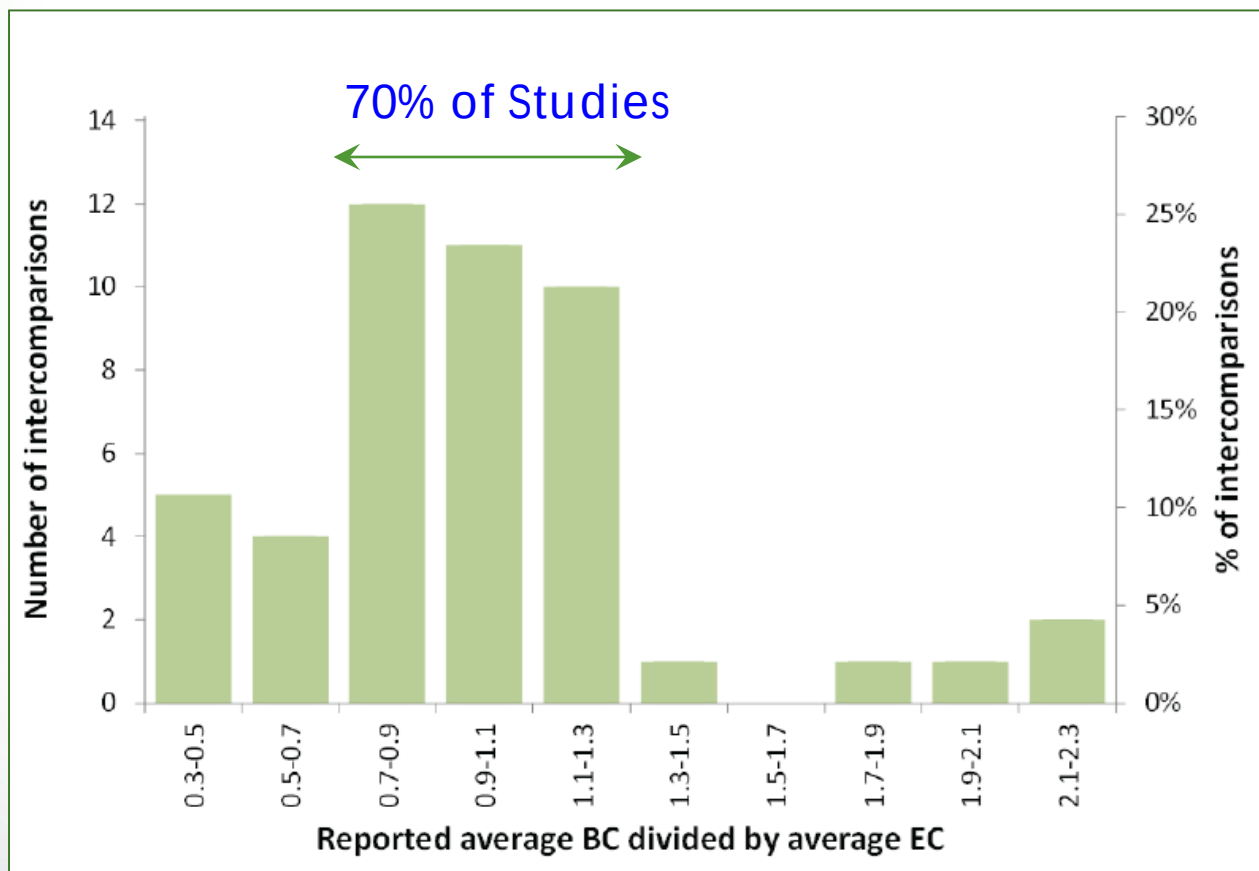
U.S. mobile sources



Total U.S. mobile source BC emissions are projected to decline by 86% by 2030 due to regulations already promulgated.

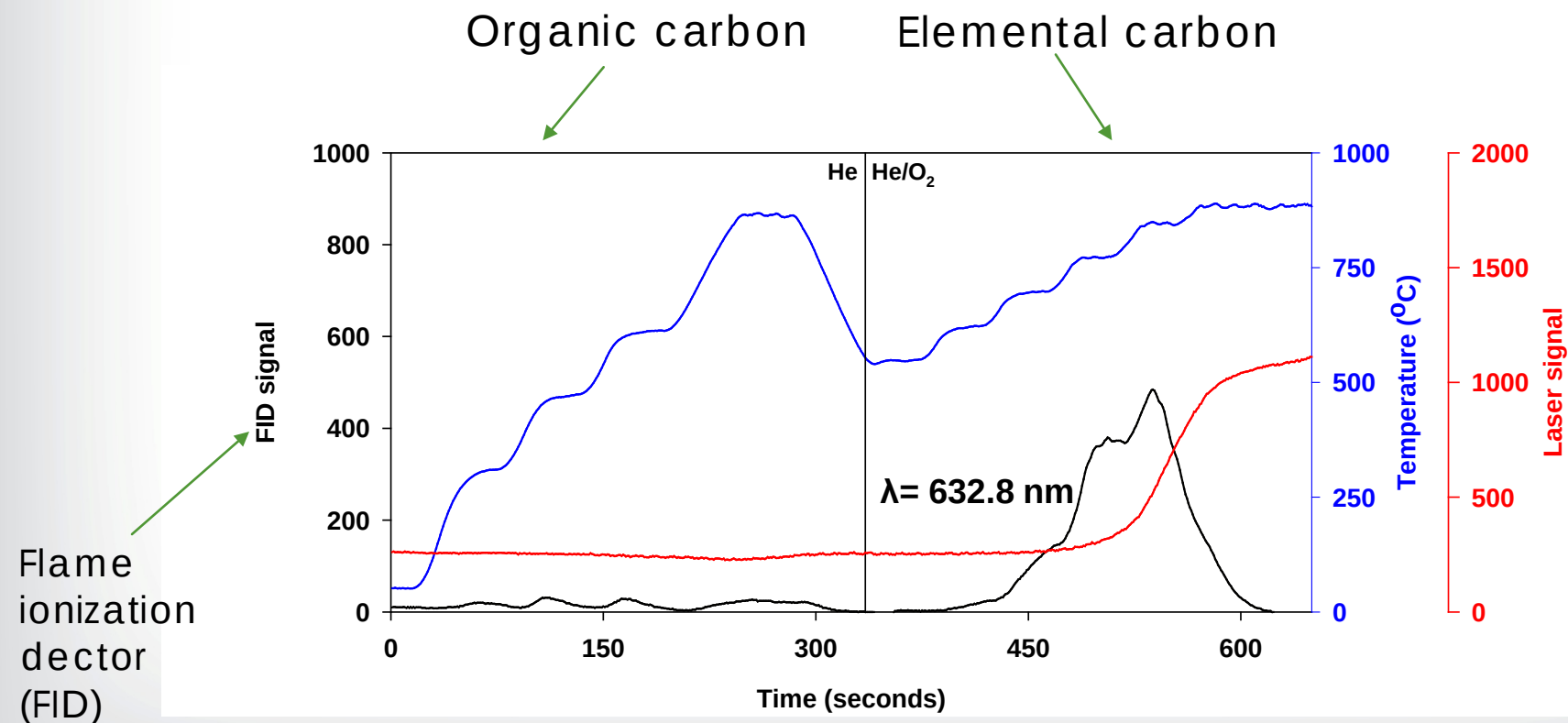
Emissions from U.S. Mobile Sources

Ambient comparisons of elemental carbon (EC) and BC often show fairly good agreement, although there are some exceptions.



Source: EPA Report to Congress on Black Carbon

- Elemental carbon is commonly measured in US ambient networks and emission factors, using operationally defined thermal/optical transmittance (TOT) or thermal/optical reflectance (TOR) methods





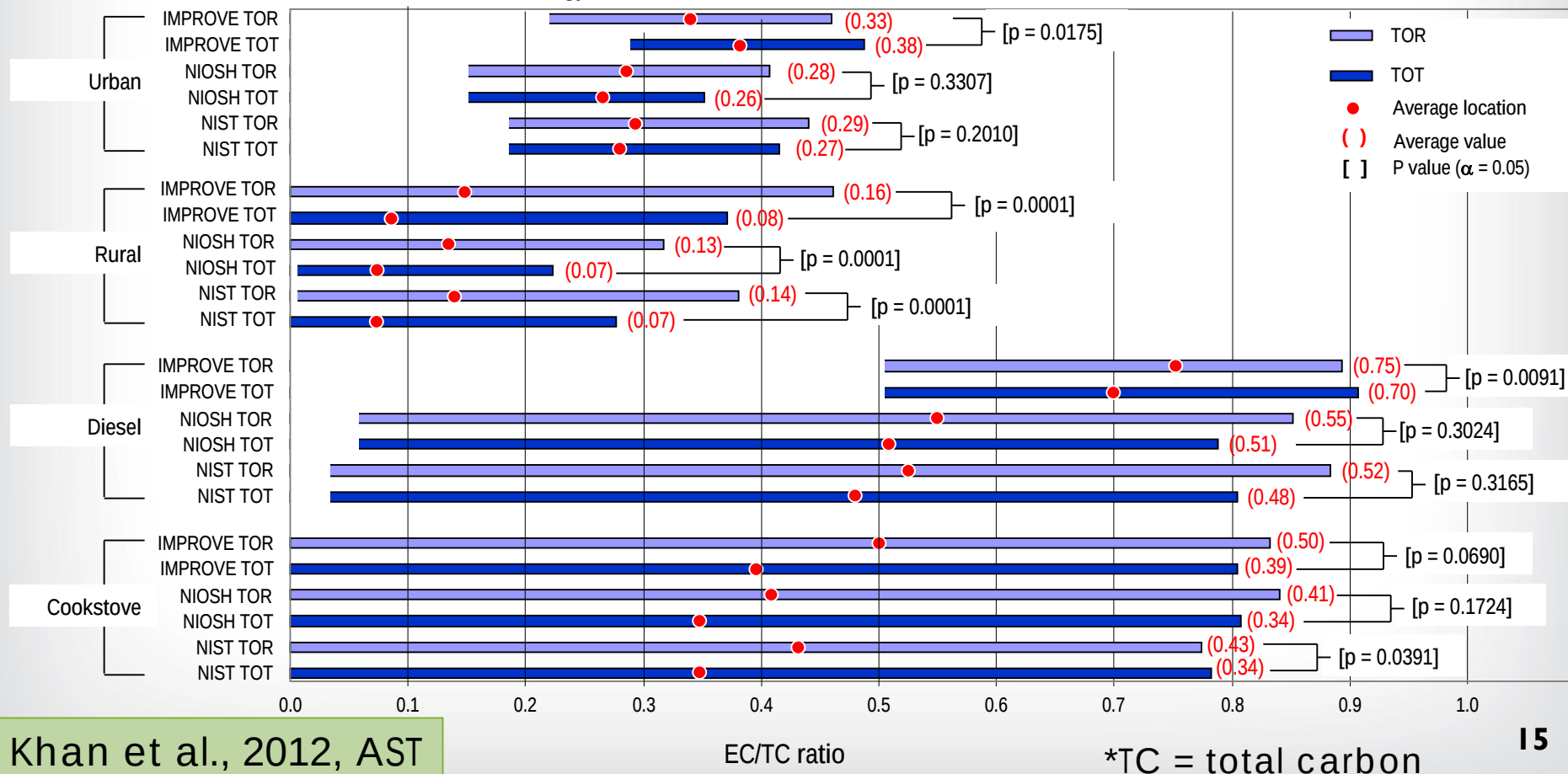
EPA Research: Methods

EPA study comparing multiple EC measurement protocols for duplicate samples: some agree closely, others show some disagreement.

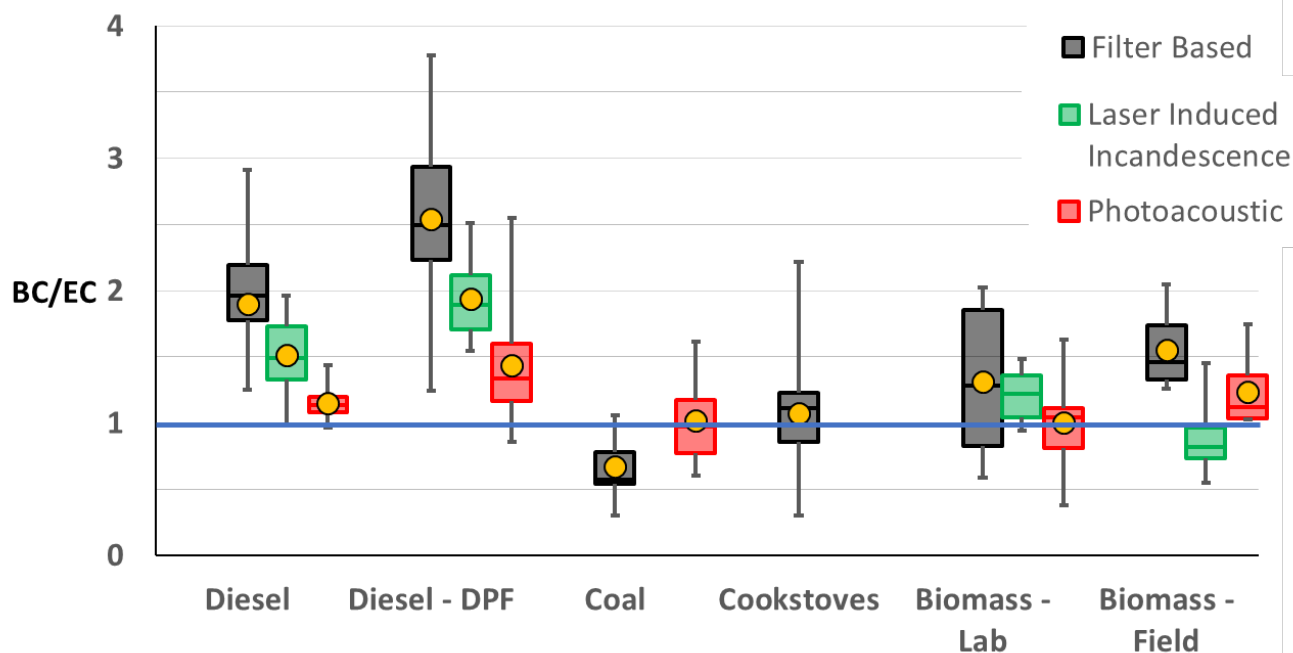
IMPROVE: Interagency Monitoring of Protected Visual Environments

NIOSH: National Institute of Occupational Safety and Health

NIST: National Institute of Standards and Technology



Comparison of multiple BC instruments against thermal-optical EC for different source emissions



Holder et al., in preparation

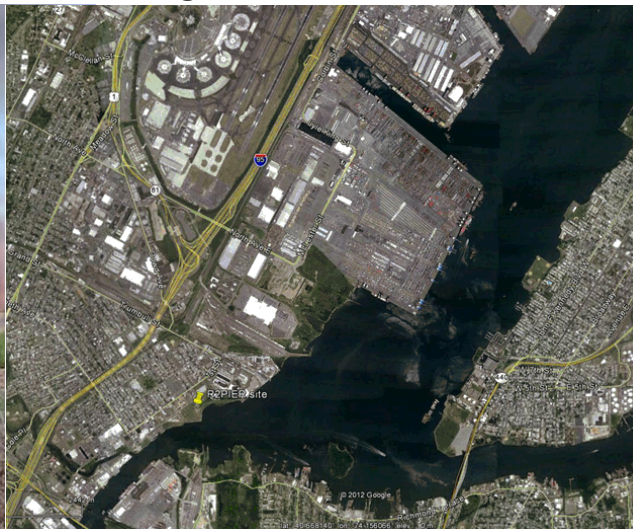


Keen interest in high-time resolution measurements for dynamic monitoring environments

Dynamic emissions



Isolating clustered sources



Mobile monitoring

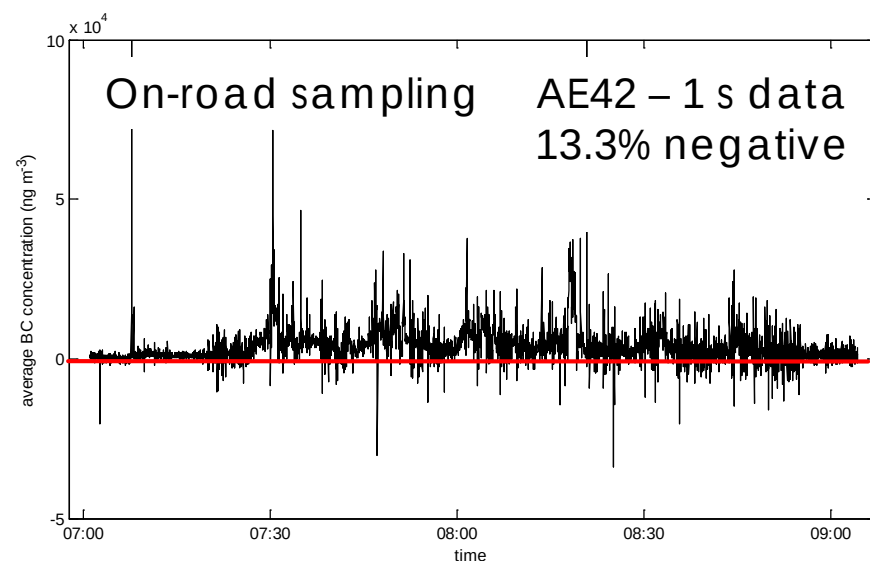
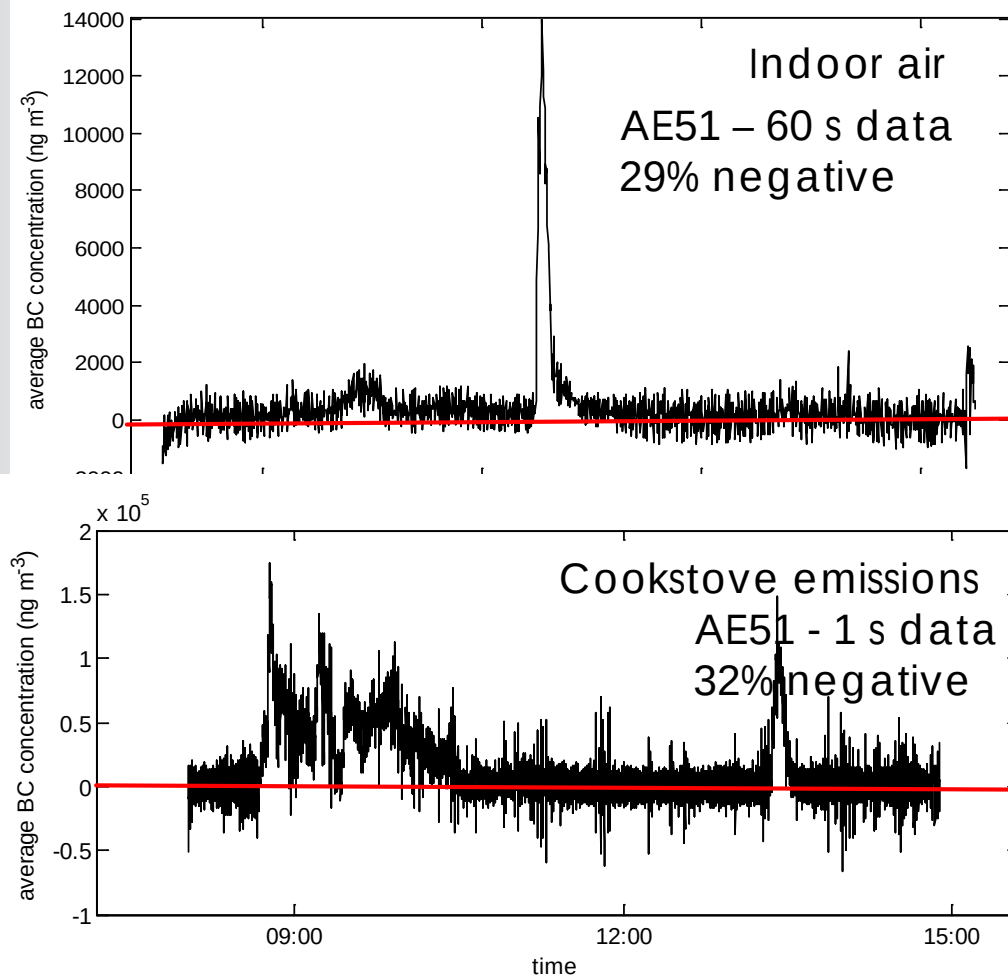


- Optical measurements (filter-based, photoacoustic, laser-induced incandescence) currently provide highest time resolution



EPA Research: Methods

Optimized noise-reduction algorithm (ONA) developed to maximize time resolution in filter-based continuous measurement (aethelometry)

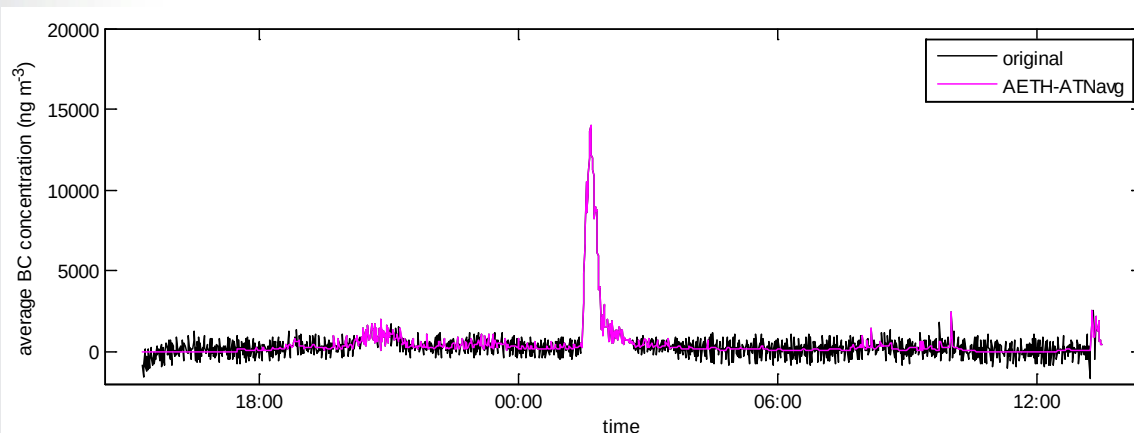


Hagler et al.,
2012, AAQR

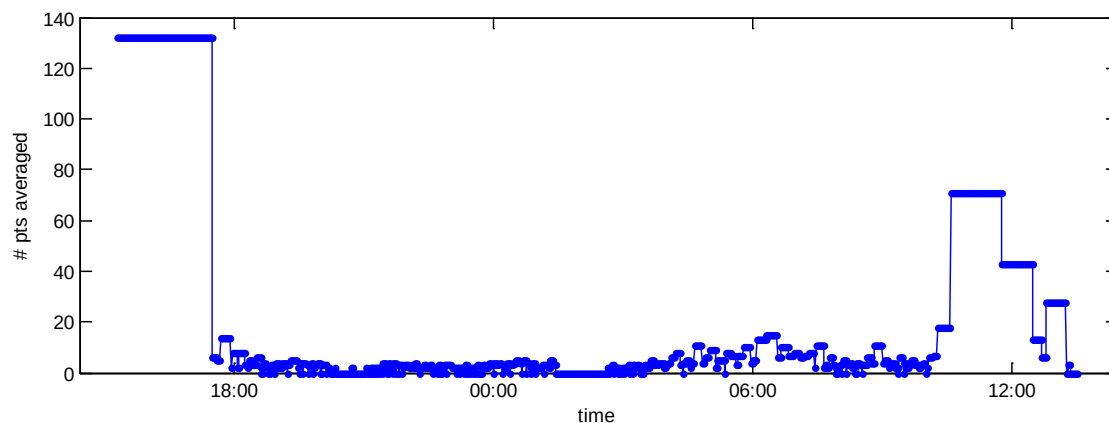


EPA Research: Methods

Optimized noise-reduction algorithm (ONA) developed to maximize time resolution in filter-based continuous measurement (aethelometry)



Reduction of negative values from 29% to ~0%, while retaining peak



Variable averaging window set by the incremental light attenuation output by aethelometers

Hagler et al.,
2012, AAQR



EPA Research: Emission Studies

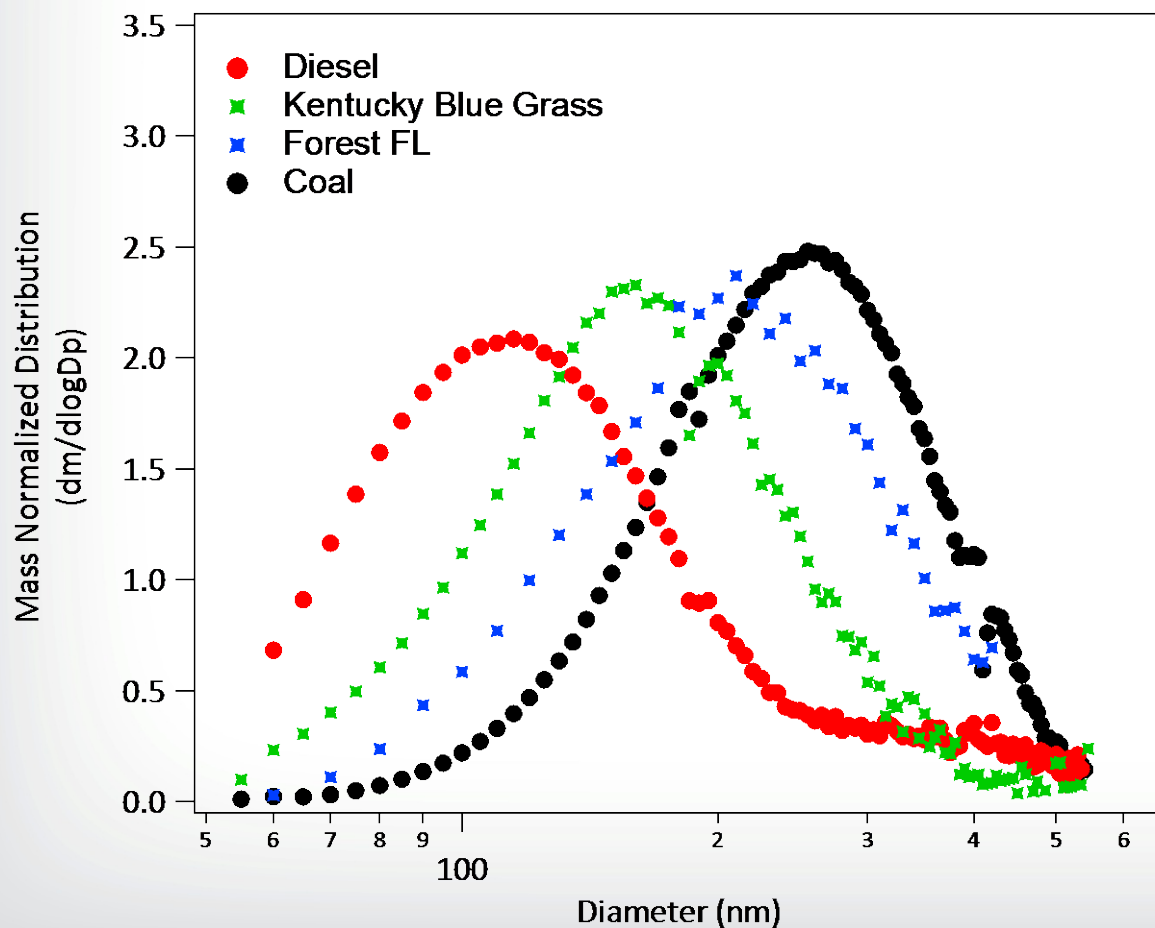
Ongoing field and laboratory research characterizing emissions, and updating emission factors in inventory, including:

- Prescribed burns and wildfires (Brian Gullett, Amara Holder)
- Aircraft emissions (John Kinsey)
- Vehicle emissions – light and heavy-duty dynamometer (Rich Baldauf, Tom Long)
- Stationary source emissions (Tiffany Yelverton, Amara Holder)
- Cookstoves (Jim Jetter, Amara Holder)



Emissions studies characterizing BC:

Black carbon size distribution by source



Holder et al., in preparation

Laser-induced incandescence

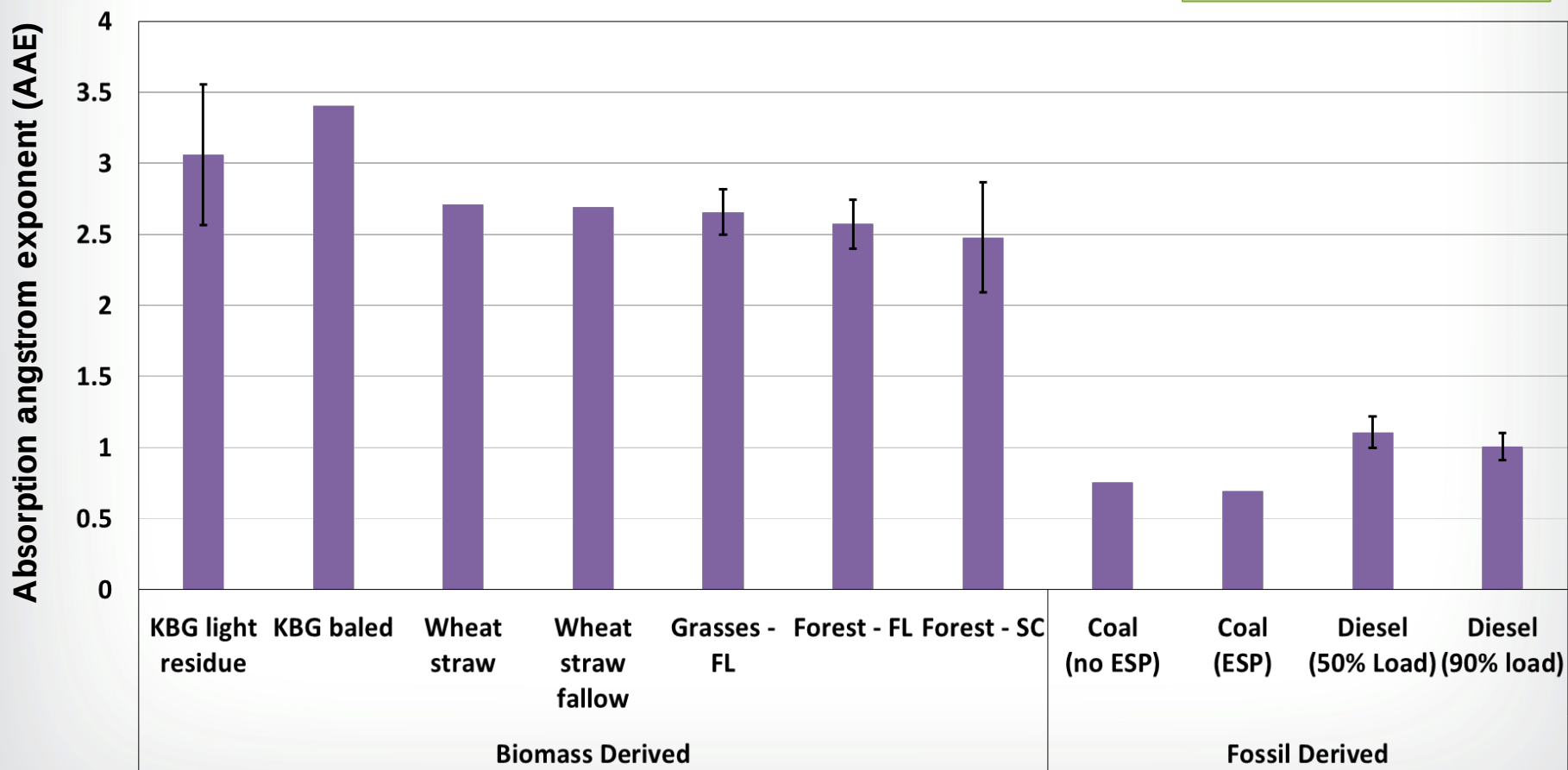




EPA Research: Emission Studies

Emissions studies quantifying BC:

Holder et al., in preparation



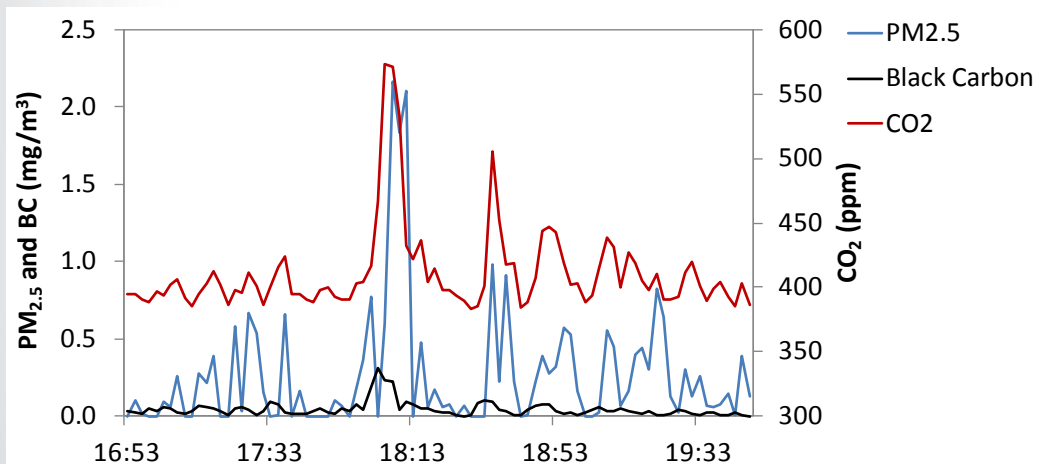


EPA Research: Emission Studies

In situ sampling with AeroStat: integrated and real-time measurements



Image: aethlabs.com



Project lead: Brian Gullett

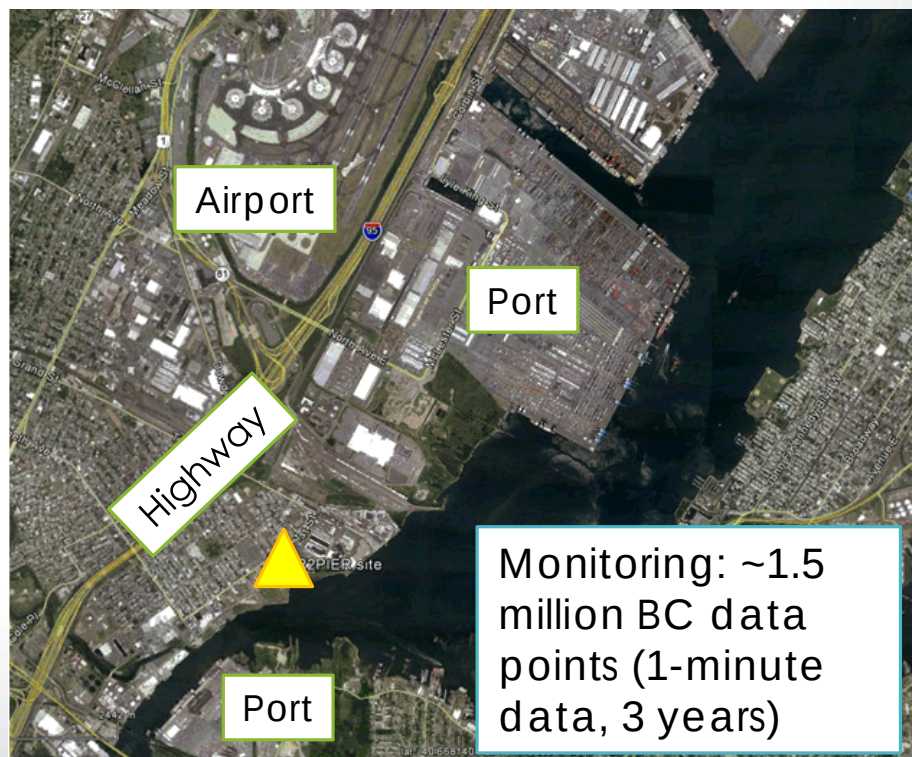
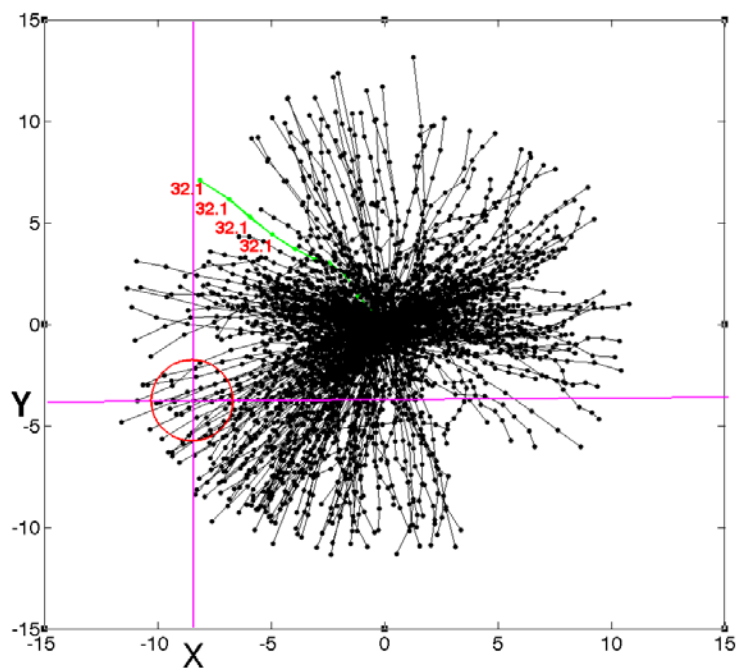




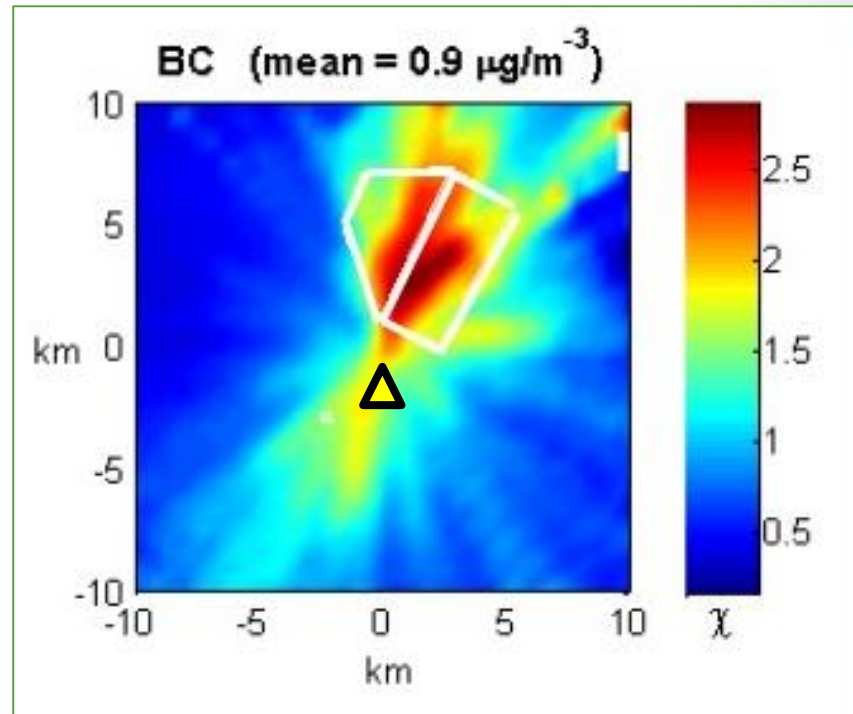
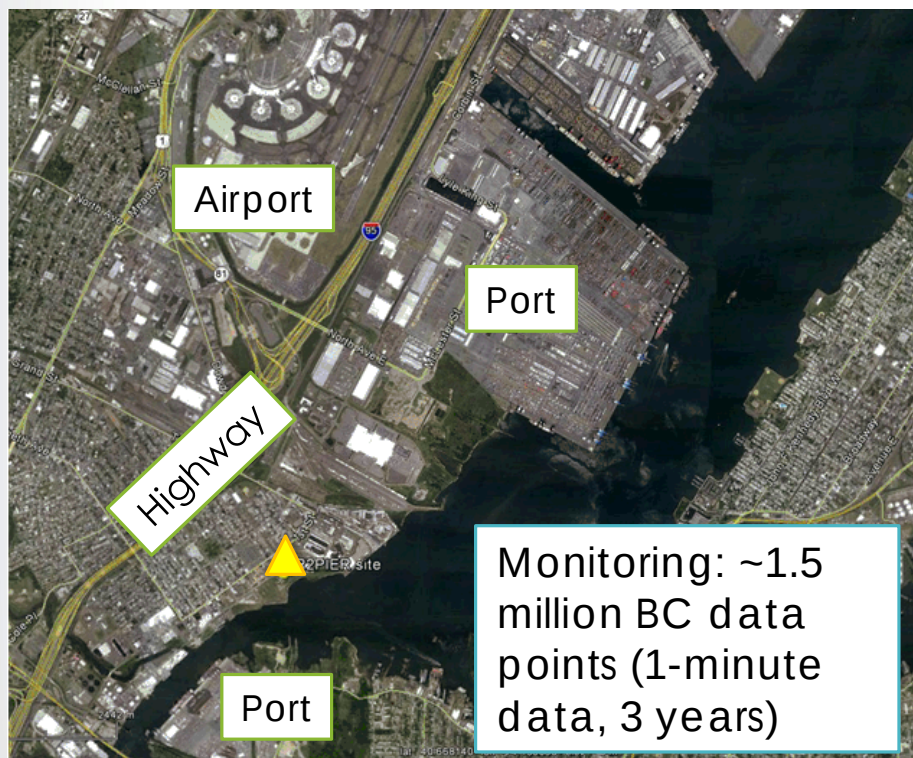
EPA Research: Near-Source

R2PIER project: Combining high-time resolution stationary sampling, with inverse local back trajectory modeling, to look at emission area changes with time.

EPA leads:
Gayle Hagler
Dan Birkett



R2PIER study: example results for one month of the study





EPA Research: Near-Source

Ongoing research on BC and co-emitted pollutant concentrations near highways, rail yards, ports; mitigation strategies

Example: Cicero Rail Yard Study (EPA Region 5 study)

EPA ORD lead:
Gayle Hagler





EPA Research: Near-Source

Ongoing research on BC and co-emitted pollutant concentrations near highways, rail yards, ports; mitigation strategies

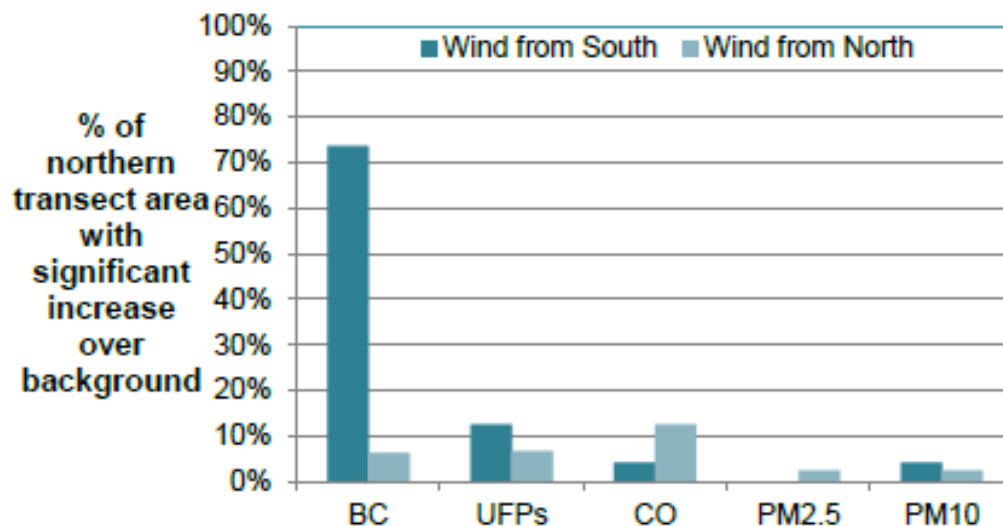
Example: Cicero Rail Yard Study (EPA Region 5 study)

Source: Cicero Rail Yard Study Final Report, 2014 (EPA/600/R/12/621)

Example findings from mobile sampling

For 3 early morning sessions with wind from S: "...excess concentration of 0.3-0.6 $\mu\text{g m}^{-3}$ BC, 30-40% higher total BC concentrations relative to the urban background (background ranged 0.8-2.0 $\mu\text{g m}^{-3}$ BC). The other measurements shown – UFPs, CO, PM_{2.5}, and PM₁₀ – do not show the same upwind/downwind trend of excess levels."

4-7 AM timeframe



*UFPs = ultrafine particles (<100 nm)

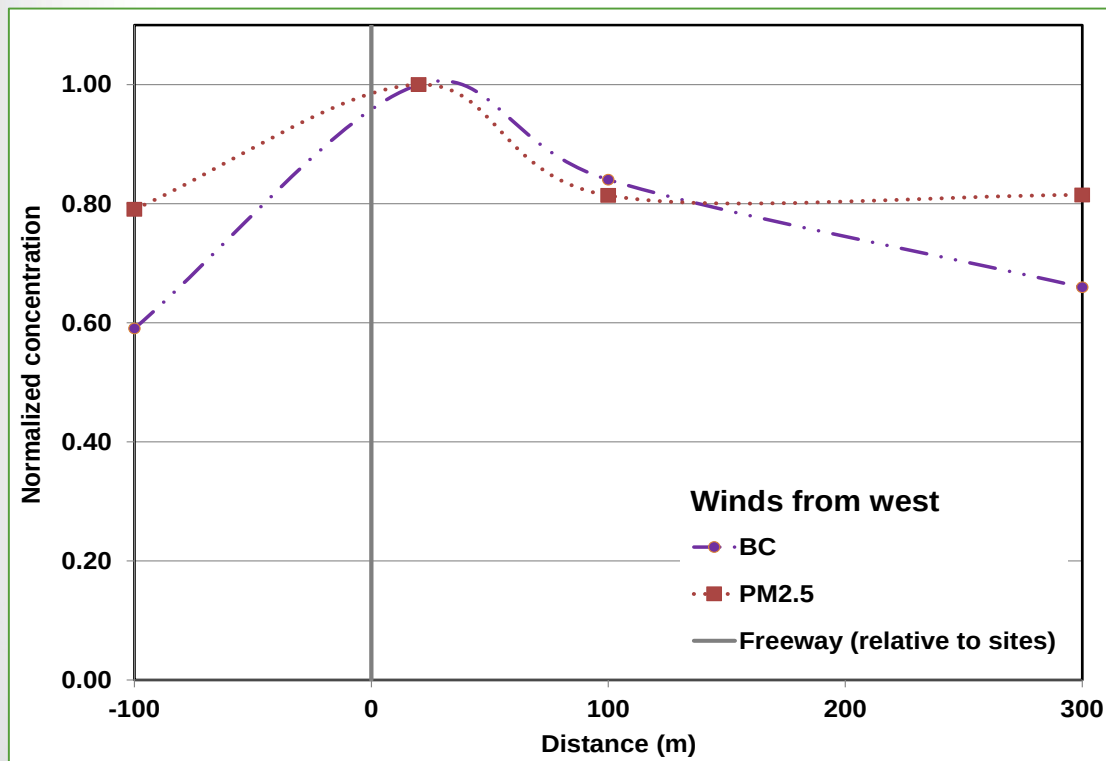


EPA Research: Near-Source

Ongoing research on BC and co-emitted pollutant concentrations near highways, rail yards, ports; mitigation strategies

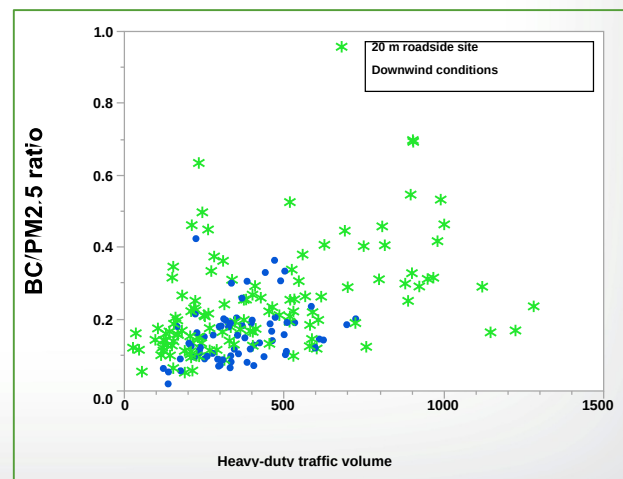
Example: Las Vegas Near-Road Study

Source: Kimbrough et al., in preparation



~40% difference in BC

~20% difference in PM_{2.5}





EPA Research: Grantees

EPA's extramural grant program:

Website: <https://www.epa.gov/research-grants/air-research-grants>

New: Particulate Matter and Related Pollutants in a Changing World

Seven of 13 future grants to investigate some aspect of wildfire impact on pollution and human health, e.g.:

- How climate and land use might change wildfire activity in the future
- Assessment of future land use policies
- How to appropriately model black and brown carbon from fires at different scales

Clean Air Research Centers

2012: Measurements and Modeling for Quantifying Air Quality and Climate Impacts of Residential Biomass or Coal Combustion for Cooking, Heating and Lighting

2010: Black carbon's role in global to local-scale climate and air quality



Summary

- U.S. BC emissions have been declining, and additional reductions are expected by 2030 due to controls on mobile diesel engines.
- Ongoing partnership by EPA in international collaborations focused on black carbon emissions.
- Controlling direct PM_{2.5} emissions from sources can be a highly effective air quality management strategy, with major public health benefits.
- Black carbon continues to be an important research focus for EPA's Office of Research and Development
 - Measurement methodology
 - Characterization of aerosol optical and chemical properties of emission sources.
 - Useful as an indicator of source emissions impact on local air quality



Thank you!

- Many EPA colleagues noted on the slides – please feel free to directly reach out to them, or contact me and I am happy to help make connections for you.

Gayle Hagler

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