US EPA Perspective on Black Carbon Emissions

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IPCC Expert Meeting on Short-lived Climate Forcers
Geneva, Switzerland, 28-31 May 2018

Overview of Presentation

- General information on the NEI (National Emissions Inventory)
- US EPA approach to quantifying PM2.5 and Black Carbon (BC/EC) emissions in the NEI
- SPECIATE database
- BC data in the 2014 NEI
- Sectors of interest for BC
  - Residential wood combustion
  - Agricultural burning
  - Mobile sources (Transportation), including marine shipping
- Next steps

National Emissions Inventory (NEI) Basics

- Types of emission sources included and resolution
  - Point sources (facility-process for ~87,000 facilities)
    - Examples include electric generation and industrial facilities
  - Nonpoint sources (county-process)
    - Onroad mobile sources: exhaust, evaporative, brake and tire wear, road dust
    - Nonroad mobile sources: lawnmowers, construction, farm, and mining equipment; aircraft, ships, and railroads
    - Biogenic soil and vegetation (county-process)
    - Other nonpoint sources: residential heating, gas stations, animal waste, solvents, fugitive dust
  - Wild and Prescribed Fires (daily-point)
- States, locals and tribes (SLTs) submit CO, SOX, NOX, VOC, PM10, PM2.5, NH3 and Lead
  - Hazardous Air Pollutants (HAPs) and Greenhouse Gases (GHGs) can also be voluntarily submitted
- The NEI is the result of combining emission estimates from EPA with SLTs
- The full NEI is on a 3-yr cycle (e.g. 2008, 2011, 2014, 2017) and larger point sources submit annually

Five Key NEI Goals

- Complete: Includes all emissions to the atmosphere included, whether regulated or unregulated for all counties including Puerto Rico and the Virgin Islands
- Represents the year of the inventory
- Uses best available information
- Transparent - includes the emissions origin
  (who provided, factor, activity, method)
- Timely

General NEI Emission Estimation Methods

- Source-specific activity and emission measurements
- Source-specific emissions process models
  - MOVES for on-road and non-road emission estimates
  - SMARTFire2/BlueSky for Wildland Fires (day-specific emission estimates)
- Emission Factors
  - Site-specific
  - Industry-average
  - See AP-42/WEBFIRE examples: https://cfpub.epa.gov/webfire/
  - Emissions estimated as: (EF) x (activity) x Control Factors
- Mass Balance
- NEI is a combination of SLT-submitted data combined with EPA estimates used to “backfill”

How are Black Carbon emissions developed in the NEI?

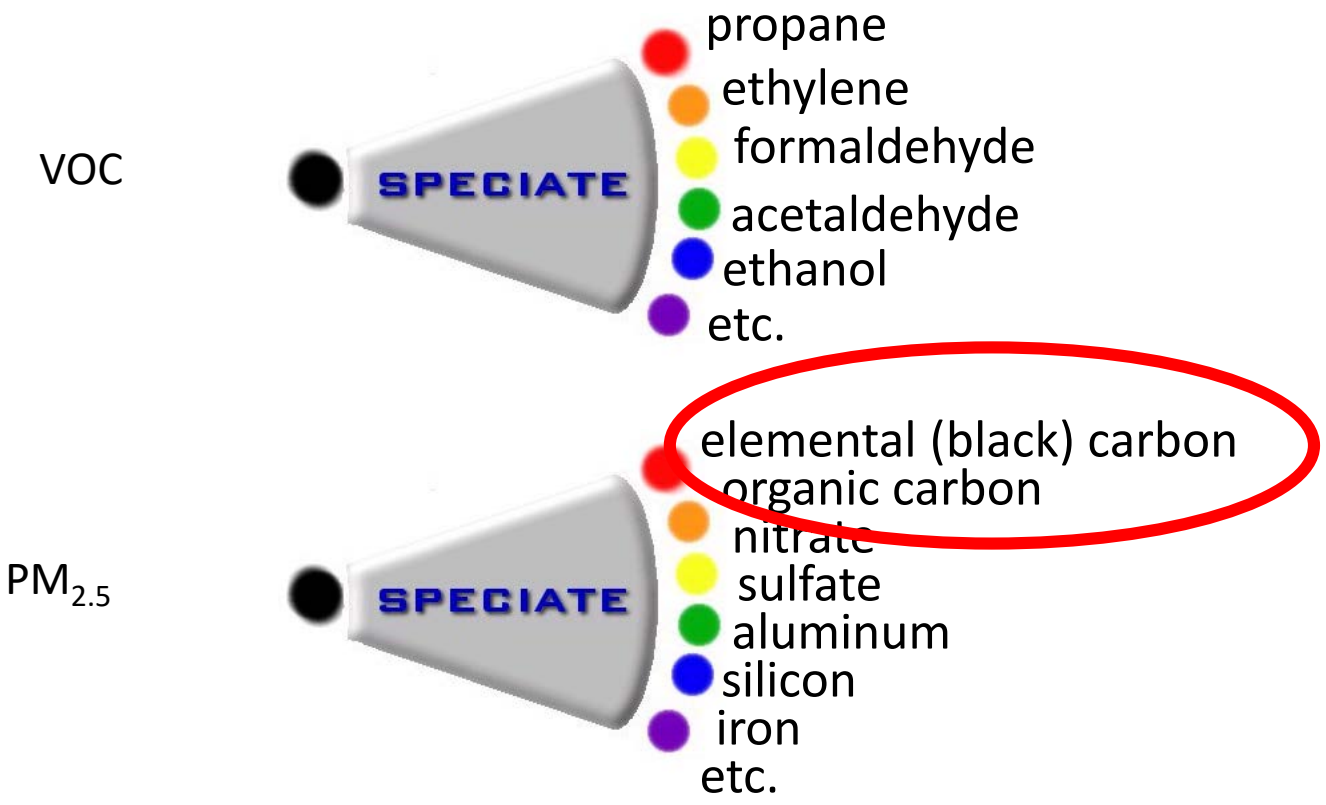
- Most of the black carbon (BC) estimates are result of applying speciation profiles for elemental carbon (EC) to PM2.5 emissions
  - In the NEI, EC estimates are used to represent BC
  - Nearly all EC profiles are based on IMPROVE's TOR (Thermal Optical Reflectance) methods
- On road mobile source emissions of BC come directly from the EPA model (MOVES) and represent engine test results
- While BC estimates are produced as part of the process to produce species for air quality modeling, they are also now included as a pollutant in the NEI
- BC emissions reported to UN Economic Commission for Europe (UNECE) Convention on Long-range Transboundary Air Pollution (CLRTAP)
- 2012 BC Report to Congress covers details on US emissions reporting

US Reporting to LRTAP Program

- Voluntarily reported national PM2.5 emissions for over 10 years
- Annual PM reporting per Gothenburg Protocol 2012 Amendments, accepted by US in 2017
  - Region-level PM2.5 emissions also reported for US Pollutant Management Area (PEMA) per Gothenburg
- Voluntary BC emissions reporting began in 2014
  - National estimates for year 2011
  - Since then: updates to 2011 and estimates for year 2014

WHAT IS SPECIATION?

Speciation disaggregates inventory species (e.g. VOC, $PM_{2.5}$) into more detailed species



More information about SPECIATE

- A repository for speciated emissions profiles
- A searchable Microsoft Access database and online database
- Profiles for three air pollution emission types:
  - Particulate Matter (PM)
  - Total Organic Gases (TOG)
  - Other Gases/pollutants [Hg, $NO/NO_2/HONO$, semivolatile organic compounds (SVOC)]
- Available on EPA Website: https://www.epa.gov/air-emissions-modeling/speciate-version-45-through-40
- Nearly all SPECIATE profiles come from the literature or from otherwise credible source testing programs

The steps in PM2.5 Speciation to Black Carbon

Emissions of $PM_{2.5}$ are reported for a specific Source Classification Code (SCC)

Example:
100 tons of PM2.5 from prescribed burning
SCC: 2610000500

→

SPECIATE Database: Assign Speciation Profile to the Source Classification Code

Example:
Profile Code: 91109
Composite Profile – Prescribed burning

→

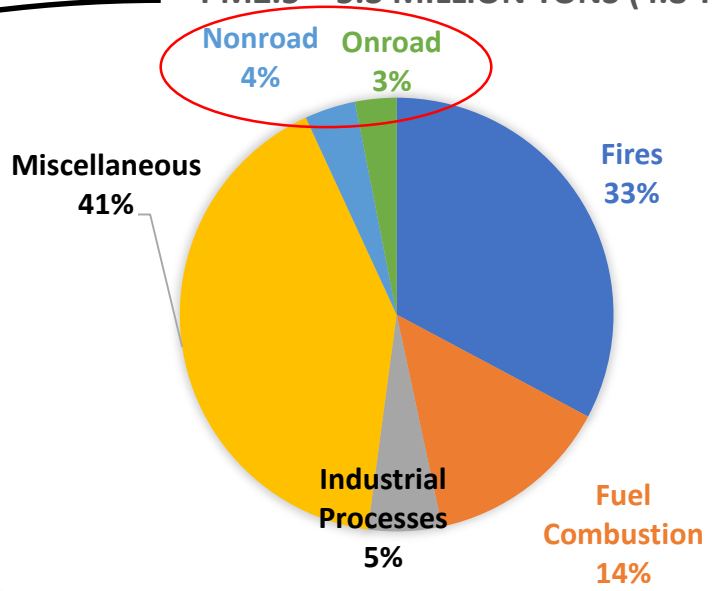
Multiply inventory emissions by profile fraction to get emissions of specific chemical compounds

Example:
50 tons organic carbon
11 tons black carbon
35 tons non-carbon organic matter, etc.

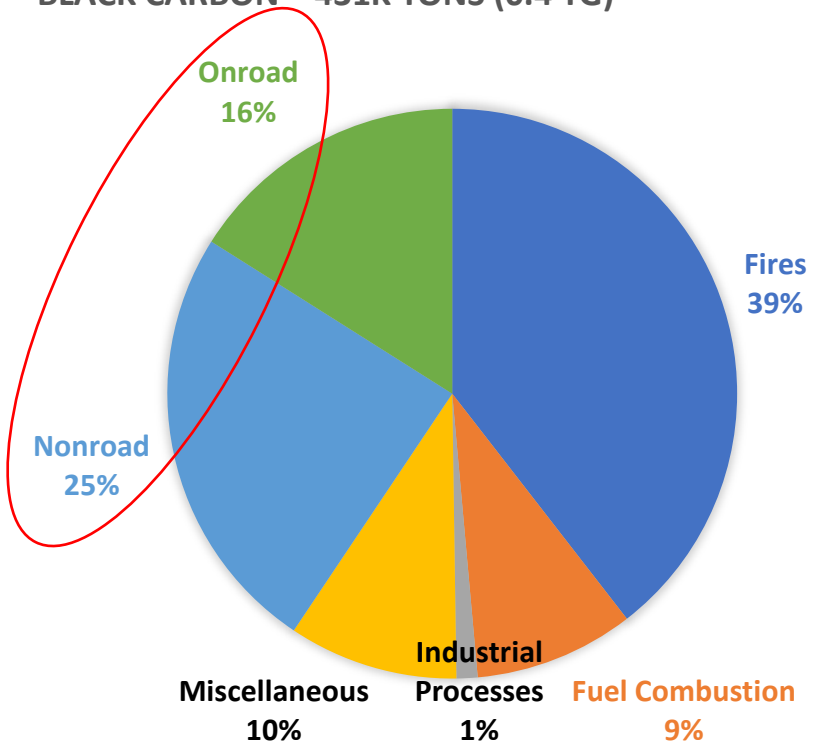
Note: there are thousands of SCCs in the NEI which need to be mapped to a few hundred profiles we have in the current SPECIATE

PM2.5, Black Carbon and Organic Carbon in the 2014 NEI

PM2.5 = 5.3 MILLION TONS (4.8 TG)

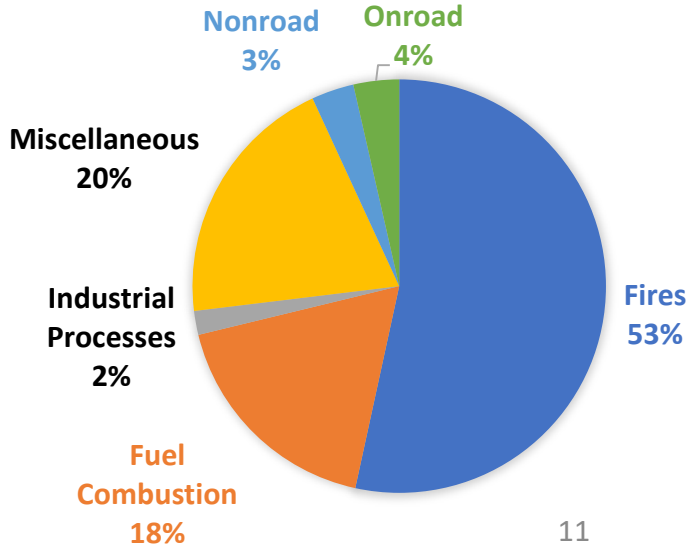


BLACK CARBON = 431K TONS (0.4 TG)

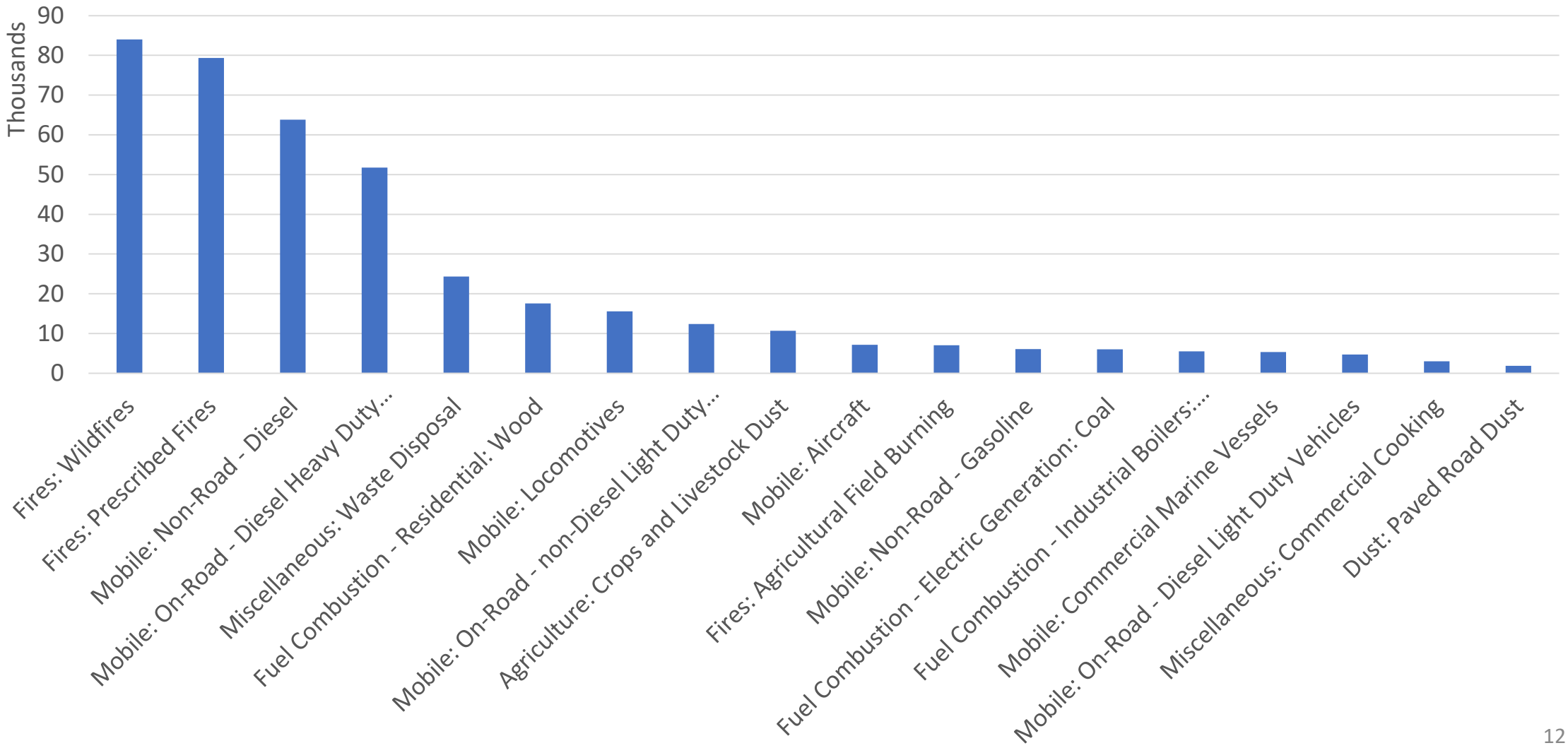


Miscellaneous includes all the dust categories

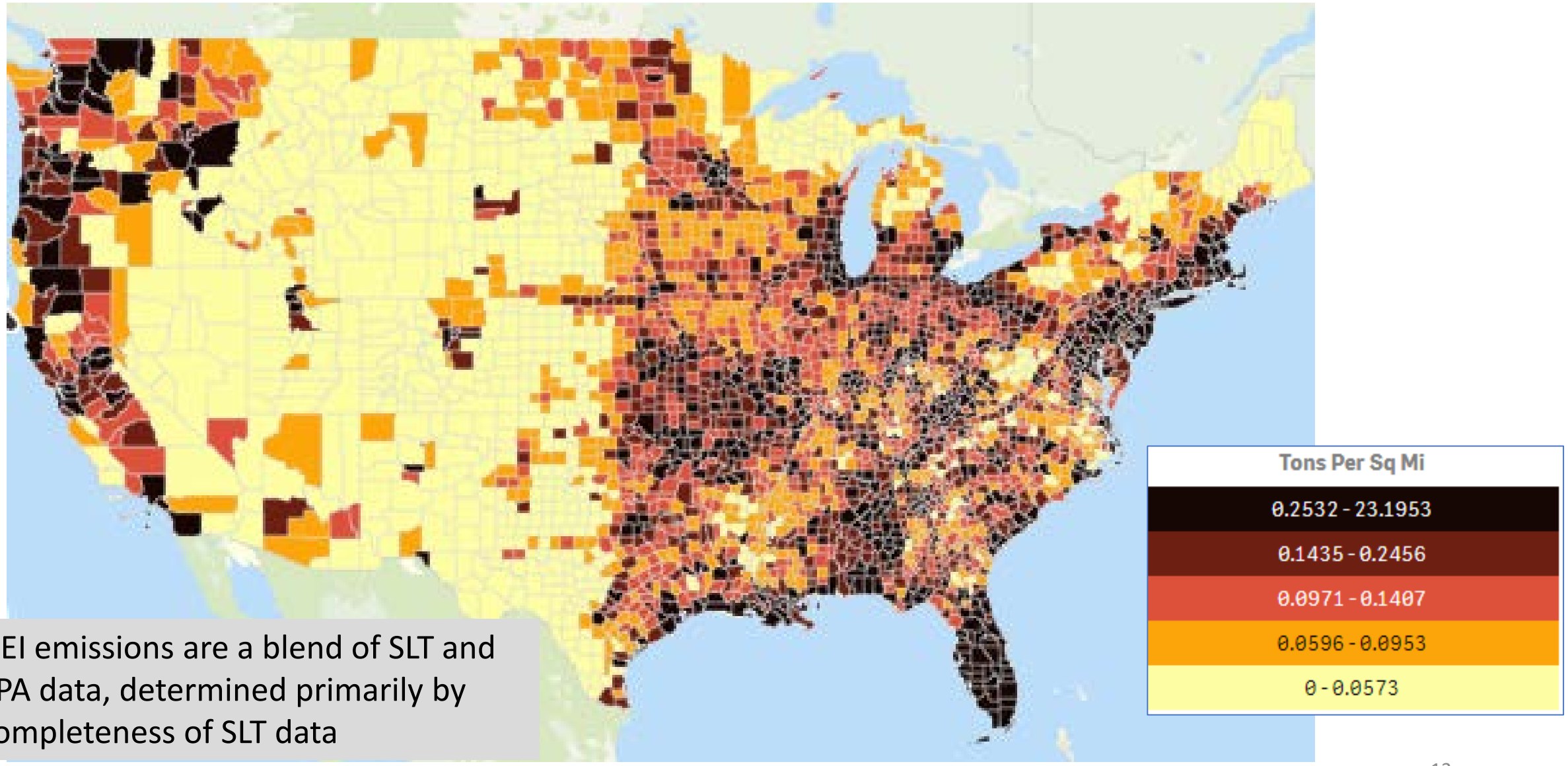
ORGANIC CARBON= 1.5 MILLION TONS (1.4 TG)



Black Carbon Emissions (short tons) by Sector

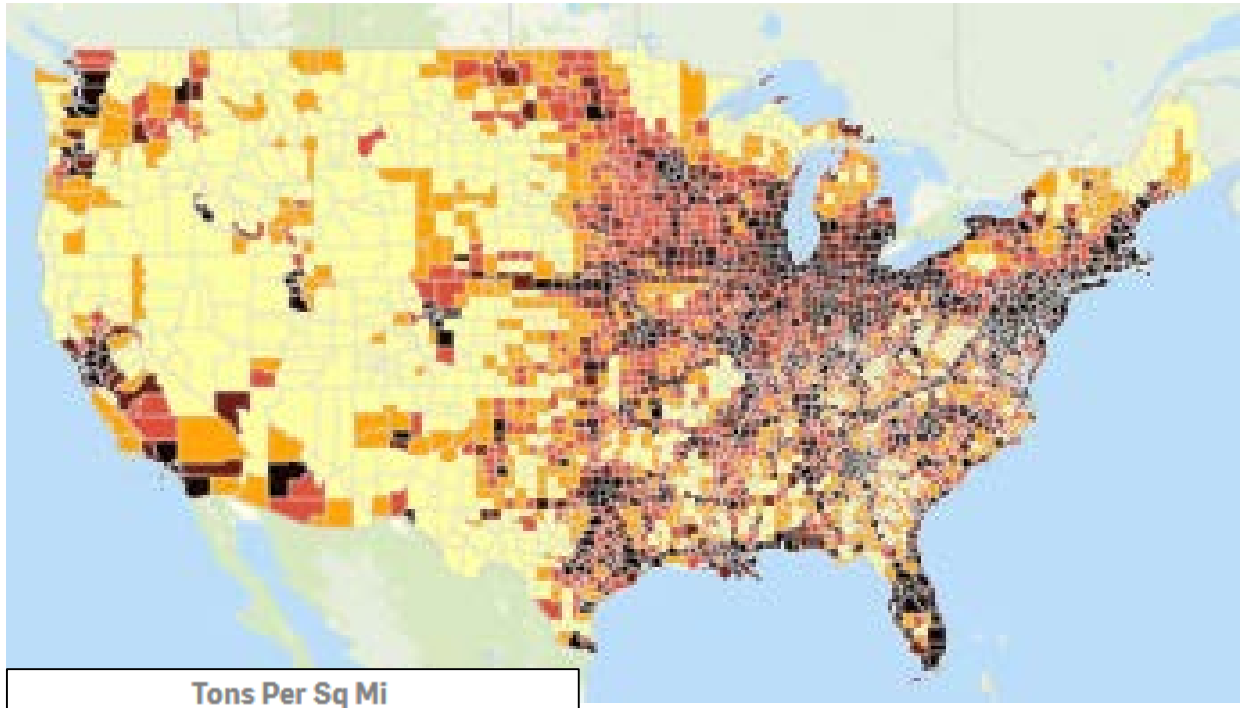


County Distribution of Total Black Carbon in the 2014 NEI



NEI emissions are a blend of SLT and EPA data, determined primarily by completeness of SLT data

Black Carbon: Mobile (left), Residential Wood Combustion (right)



Tons Per Sq Mi
0.1157 - 18.8494
0.0608 - 0.1114
0.0380 - 0.0594
0.0210 - 0.0372
0 - 0.0203

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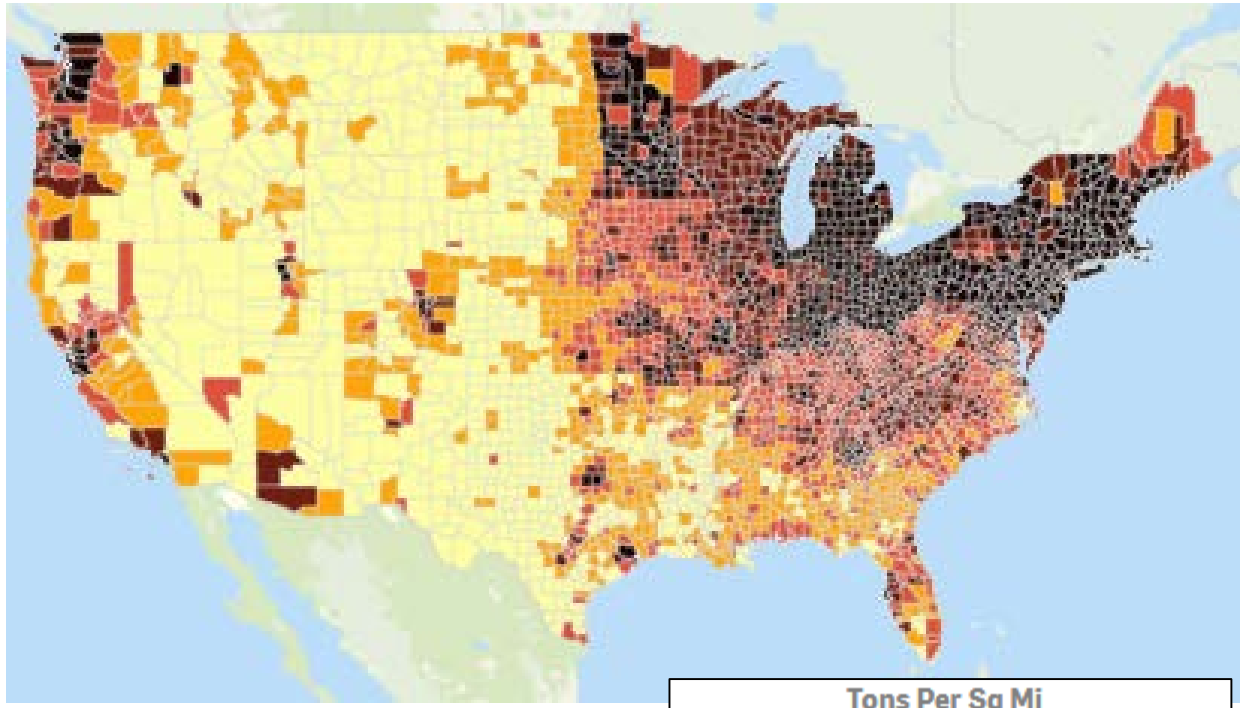


Tons Per Sq Mi
0.0153 - 0.9175
0.0066 - 0.0148
0.0029 - 0.0064
0.0009 - 0.0028
0 - 0.0009

Residential Wood Combustion (RWC) Sector

- This source category includes residential wood burning devices such as fireplaces, fireplaces with inserts (inserts), free standing woodstoves, pellet stoves, outdoor hydronic heaters (also known as outdoor wood boilers), indoor furnaces, and outdoor burning in firepits and chimeneas.
- EPA estimates emissions for this sector using this simple equation: Emissions = Home Types × Appliance Fraction × Burn Rate × WoodDensity × Adjust Factor x Emission Factor
- Black carbon emissions: 17,590 tons, 4% of total

Residential Wood Combustion Developments

- Emission factors needs longer-term additional work for all appliance types
  - EPA/ORD is working to address the PM and VOC EF and speciation needs from this sector
- Fledgling RWC survey to cover at least 15 states
  - Commission for Environmental Cooperation (CEC)-funded, results hopefully can be used in 2017 NEI
  - Seeking improved characterization of appliance counts and burn rates vs current broad (5 Census region) approach with climate data
  - Targets all appliance types and vastly-different areas to hopefully allow for improved spatial mapping to all areas
  - Oversampling 6 northeast states already thinly-sampled by another survey

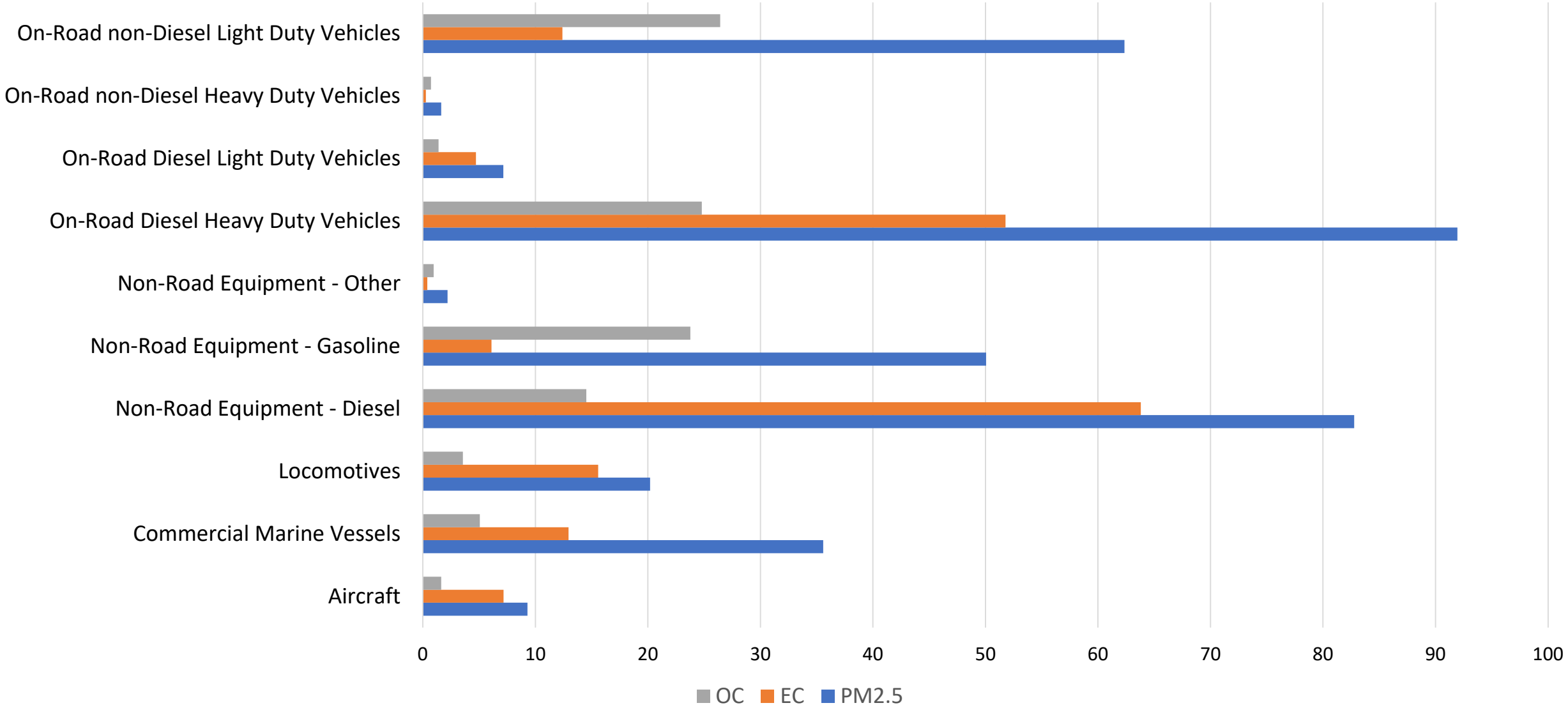
Agricultural Burning Sector

- This sector contains emissions from both crop residue burning as well as grassland burning. Different crops and grasses are represented by 25 SCCs.
- Methods are based on published improvements to previous techniques of Dr. Jessica McCarty
- Activity data (acres burned) mostly obtained from satellite detects/cropland data layer maps and SLT-based information. The biggest uncertainty in this sector is in obtaining/computing acres burned by crop type.
- Emission factors come from the literature. Updates going on currently using in-house (ORD) test results. Development of fire PM and compositional EFs are an active on-going research item at EPA/ORD.
- Black carbon emissions: This sector is a small contributor to the total fire totals (which includes larger Wild and Prescribed fires) in the 2014 NEI: 4% of BC.

Commercial Marine Vessels (CMV) Sector

- The CMV sector includes boats and ships used either directly or indirectly in the conduct of commerce or military activity. The majority of vessels in this category are powered by diesel engines that are either fueled with distillate or residual fuel oil blends. For the purpose of this inventory, we assume that Category 3 (C3) vessels primarily use residual blends while Category 1 and 2 (C1 and C2) vessels typically used distillate fuels
- Black Carbon: 12,950 tons, 3% of total. Note that BC>OC for this sector.
- For C1 and C2 vessels "HDDV" profile is applied since they are diesel engines. C3 vessels which run on residual type fuels, are assigned a 0.5% BC fraction. Thus, there is a large discrepancy of how much of the emitted PM2.5 is BC based on these profiles, which are fuel specific.
- Future work will need to look at obtaining better PM speciation profiles for both types of CMV vessels

2014 NEI Mobile Source PM2.5, BC & OC (thousands, short tons)



- HDDV (diesel profile) of 77% BC applied to all diesel sources, is a critical future need for research and possible revision
- Totals for Mobile Sources: PM2.5 = 0.33 Tg, BC = 0.16 Tg, OC = 0.09 Tg (note OC < EC), due to diesels operations

Ongoing research at EPA for speciation

- Wild and Prescribed Fires (Open Burn Test Facility)
  - By combustion phase
  - By differing fuels representing different regions
  - By fire intensity changes
- Field measurements of agricultural and wildland fire emissions
- Possibly also investigate brown carbon
- Residential wood combustion
- Contact: Dr. Amara Holder (holder.amara@epa.gov)

Conclusions and next steps

- US Black Carbon is currently about 7-8% of global totals
- Biomass burning and diesel-powered engines are the top sources for BC emissions in the US inventory
- Speciation profiles need to be continually updated to best represent both black carbon and organic carbon emissions
- We have completed an analysis in house looking at SPECIATE and addressing which profiles need updating in a priority fashion. The "HDDV" profile is top priority to research and revise. We will publish this work soon.

Questions?

Acknowledgements: NEI Team (Rich Mason, Tesh Rao, Laurel Driver, Jennifer Snyder, Ron Ryan, Madeleine Strum, Sally Dombrowski, Rhonda Thompson), Amara Holder, Rob Pinder, Marcus Sarofim (EPA/OAP)

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Appendix

BC Science

- Formed during incomplete combustion
- Contributes to warming by directly absorbing sunlight and darkening ice and snow
- Immediate climate benefits are possible due to BC's short atmospheric lifetime (compared say to carbon dioxide)
- Influence is regional and global
- BC's warming effect is offset somewhat by cooling from light-scattering pollutants (OC, SO4, etc.)
  - Traditional diesel exhaust is mostly BC
  - Residential wood combustion is mostly OC
  - The ratio of non-BC (conveniently stated to be OC) to BC is a simple, yet useful number
- Programs to reduce PM2.5 will also reduce BC. Since BC has been implicated in adverse health effects, programs that reduce PM2.5 (and BC) will lead to health effect benefits.

$PM_{2.5}$ Speciation Profile Example, Prescribed Burning, # 91109

- The Profiles of PM species weight fractions are specific to particle size ranges

pollutant	species	massfrac
PM2_5	POC	0.5019
PM2_5	PEC	0.1093
PM2_5	PSO4	0.0033
PM2_5	PNO3	0.0107
PM2_5	PNH4	0.0034
PM2_5	PAL	0.0005
PM2_5	PCA	0.0007
PM2_5	PCL	0.0024
PM2_5	PFE	0.0004
PM2_5	PK	0.0014
PM2_5	PMN	0.0001
PM2_5	PMOTHR	0.0125
PM2_5	PNA	0.0014
PM2_5	PNCOM	0.3513
PM2_5	PSI	0.0001
PM2_5	PTI	0.0007

POC, PEC = Carbon

PSO4, PNO3, PNH4 = inorganic ions

PNCOM = Non-Carbon Organic Mass (computed)

PAL, PCA, PCL, PFE, PK, PMN, PNA, PSI, PTI = Trace Elements

PMOTHR = what's left over