Preparation of Fine Particulate Emissions Inventories

Chapter 1 - $PM_{2.5}$ Overview

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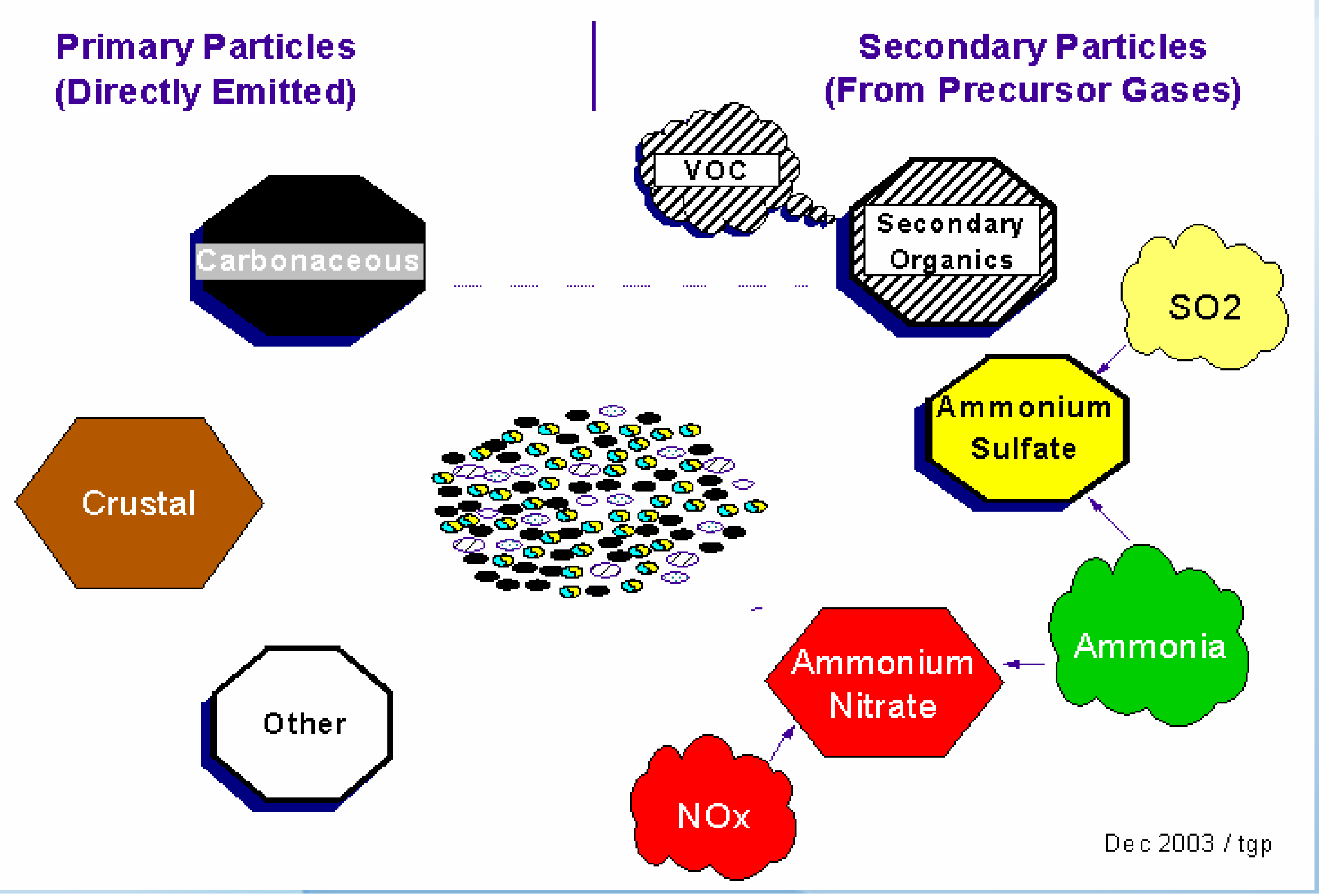
What will We Discuss in Chapter 1 and Why is This Information Important?

- After this lesson, participants will be able to describe:
  - the general composition of fine particulate matter in the atmosphere
  - how fine particulate matter are formed
  - typical composition of ambient air in 2 western areas
  - sources that contribute to the formation of fine particulate matter, nationally and in this area

What will We Discuss in Chapter 1 and Why is This Information Important?

- Why is this information important?
  - puts the local inventory efforts in perspective
  - shows how source types fit into the overall accounting of $PM_{2.5}$
  - provides a foundation for setting inventory priorities in your area

$PM_{2.5}$ In Ambient Air - A Complex Mixture



$PM_{2.5}$ Composition

- Definitions
  - **Crustal** ~ Metallic oxides in earth's crust
  - **Fugitive Dust** ~ Crustal matter emitted into the air directly, not thru a stack or vent
  - **Sulfate** ~ H_2SO_4 (condensed), $(NH_4)HSO_4$ $(NH_4)2SO_4$
  - **Nitrate** ~ NH_4NO_3
  - **Organic Carbon** ~ OC
  - **Organic Matter** ~ OC + the associated O & H
  - **CEm and CAm** ~ Multipliers to convert OC to OCM
  - **Elemental Carbon** ~ EC
  - **Primary** ~ Directly emitted
  - **Secondary** ~ Formed in air from precursor gases (generally considered to be all $PM_{2.5}$)

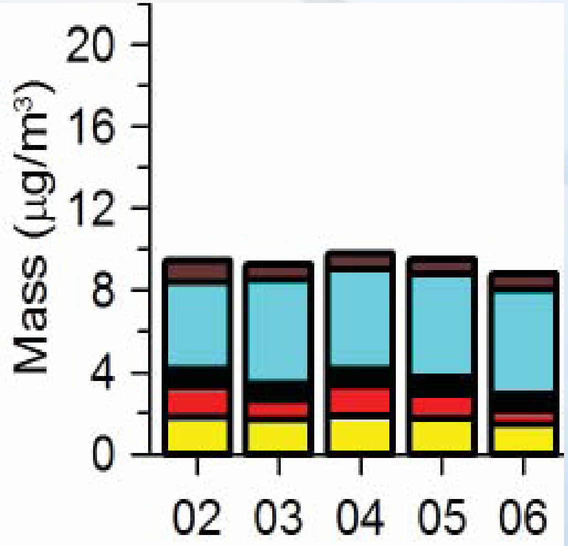
Ambient Composition is Important to…

- Identify important source types on days with high $PM_{2.5}$ concentration
- Help prioritize inventory efforts
  - Carbonaceous vs. Crustal
  - Sulfate vs. Nitrate
  - Role of Ammonia
- Help benchmark the validity of the EI

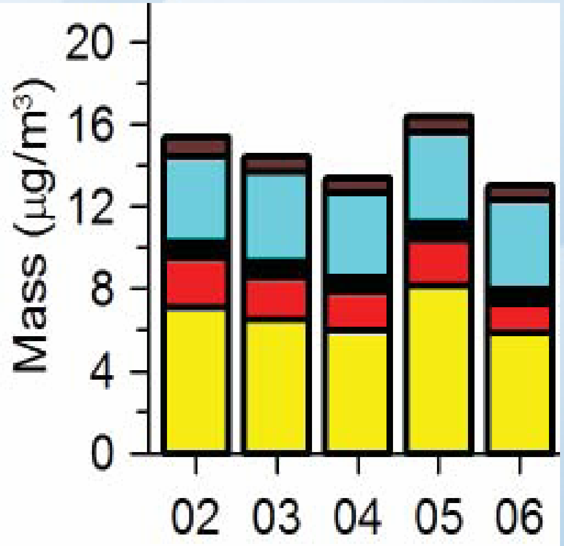
$PM_{2.5}$ Composition & its Spatial Variability

- Sulfate
  - Sulfate forms slowly, over long distances
  - Sources are usually regionally disbursed
  - Sulfate patterns relatively “flat” over large regions
- Carbon
  - Carbon has both regional & urban components
  - Carbon particles can be formed from biogenic (natural) and anthropogenic (man-made) VOC emissions
- Nitrate
  - Usually more localized
  - Tends to form in urban areas, or
  - Higher when abundance of animal or fertilizer NH_3

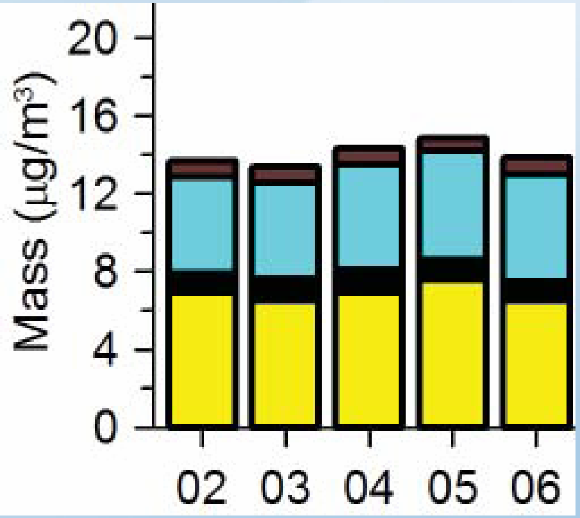
$PM_{2.5}$ Composition Regional Variability



Northwest



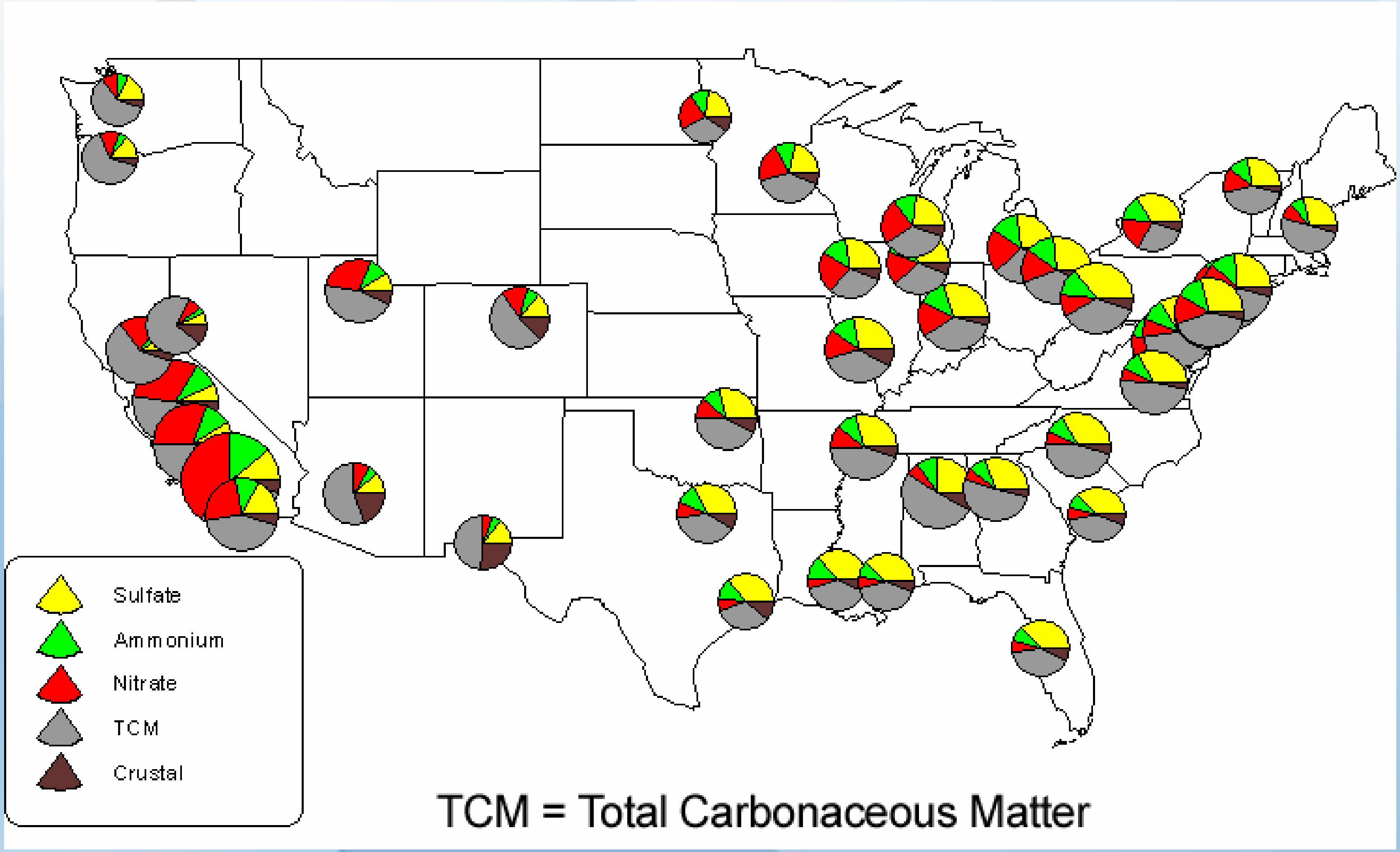
Midwest

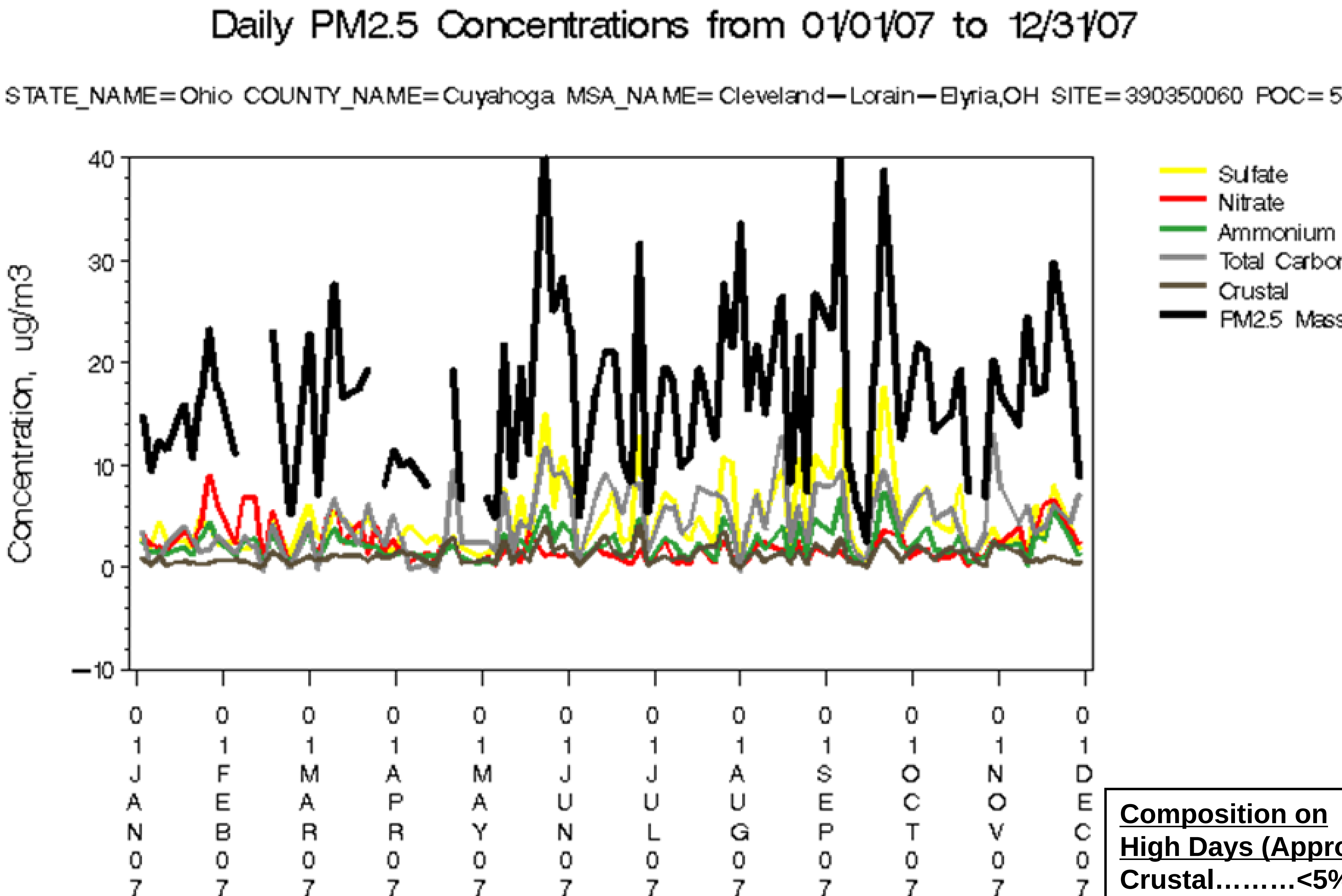


Southeast

Sulfate **Nitrate** **EC** **OC** **Crustal**

Urban (EPA STN) Annual Averages Sep 2001-Aug 2002





Source: EPA's Air Explorer (http://www.epa.gov/airexplorer/)
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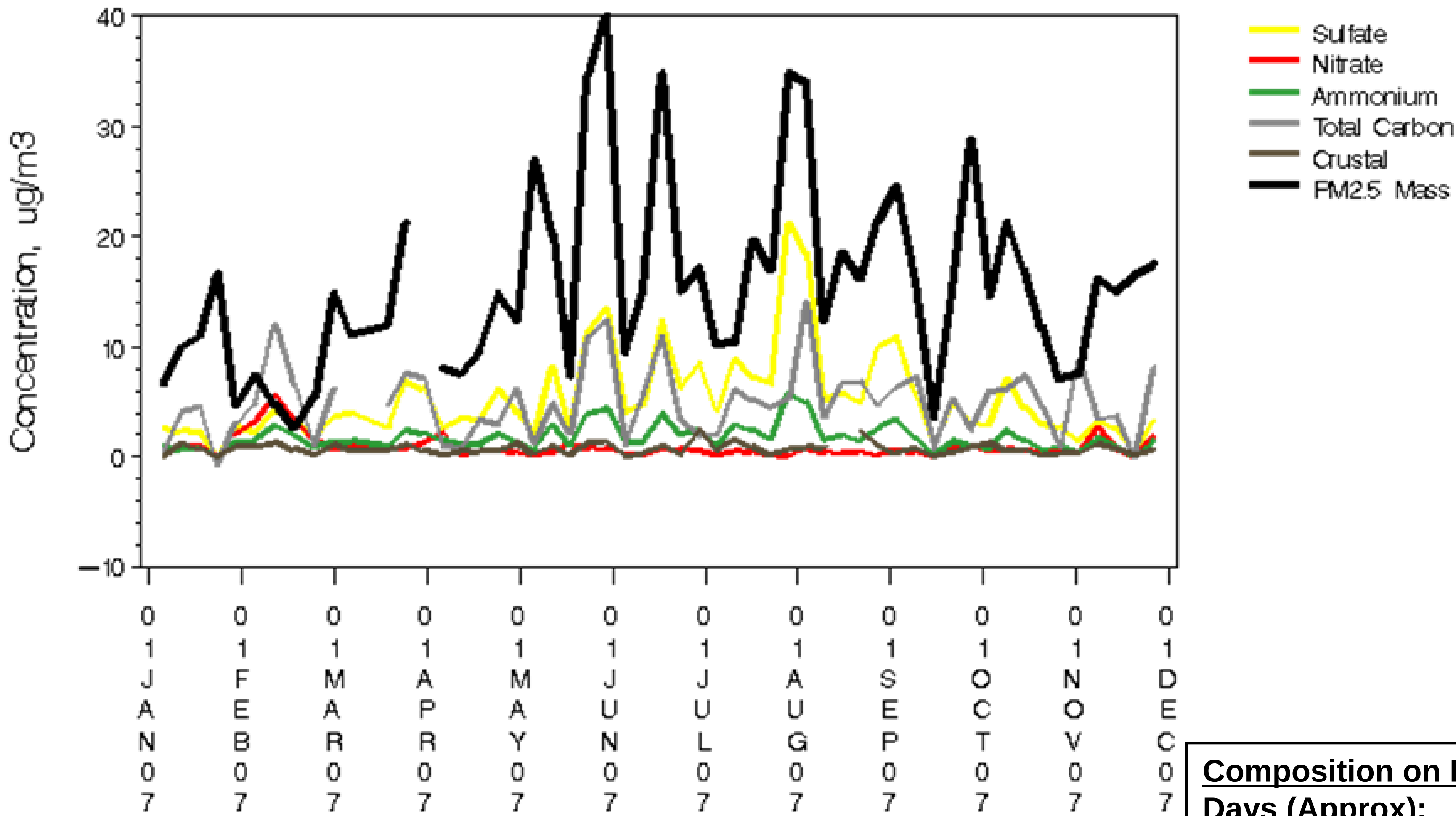
Composition on High Days (Approx):
Crustal………<5%
Total C….<20-40$^+$%
Am Sulfate 40-80%
Am Nitrate 5-30$^+$%*

Daily PM2.5 Concentrations from 01/01/07 to 12/31/07

STATE_NAME=Ohio COUNTY_NAME=Lawrence MSA_NAME=Huntington—Ashland,WV—KY—OH SITE=390870010 POC=5



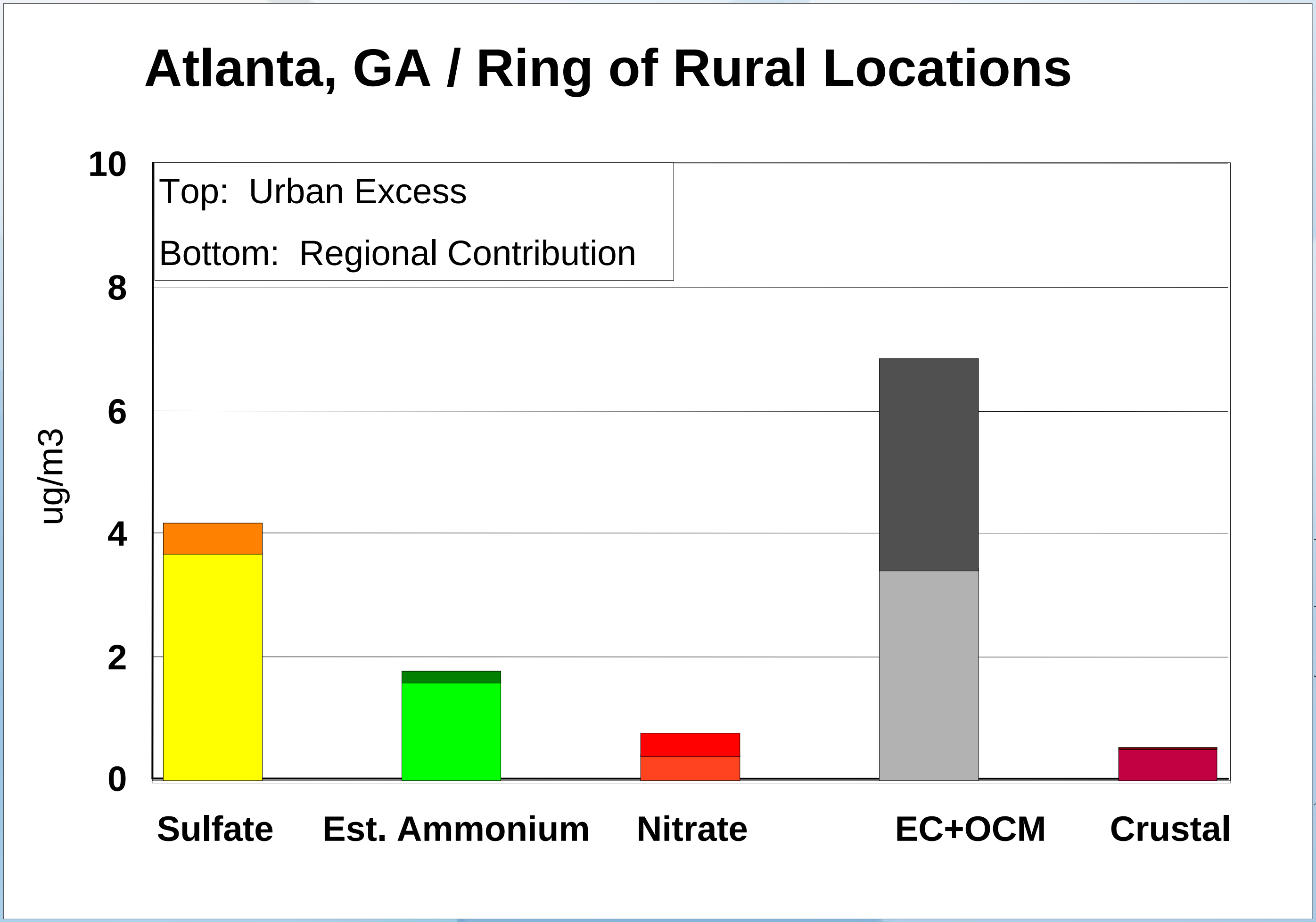
<u>Composition on High Days (Approx)</u>:
Crustal………<5%
Total C.…35-50%
Am Sulfate 30-90%
Am Nitrate… <5%*

Source: EPA's Air Explorer (http://www.epa.gov/airexplorer/)
Generated on: 28AUG09

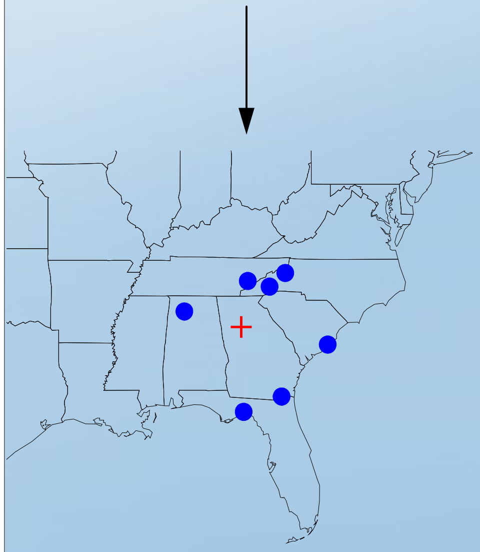
Urban Excess and its Composition

- Components of PM are higher in the urban area than in the surrounding area
- Urban Excess is that part of the urban AQ that is higher than in surrounding areas
- Simplistically, urban excess is assumed mostly associated with urban sources

"Urban Excess" Concept in ***Atlanta, GA***

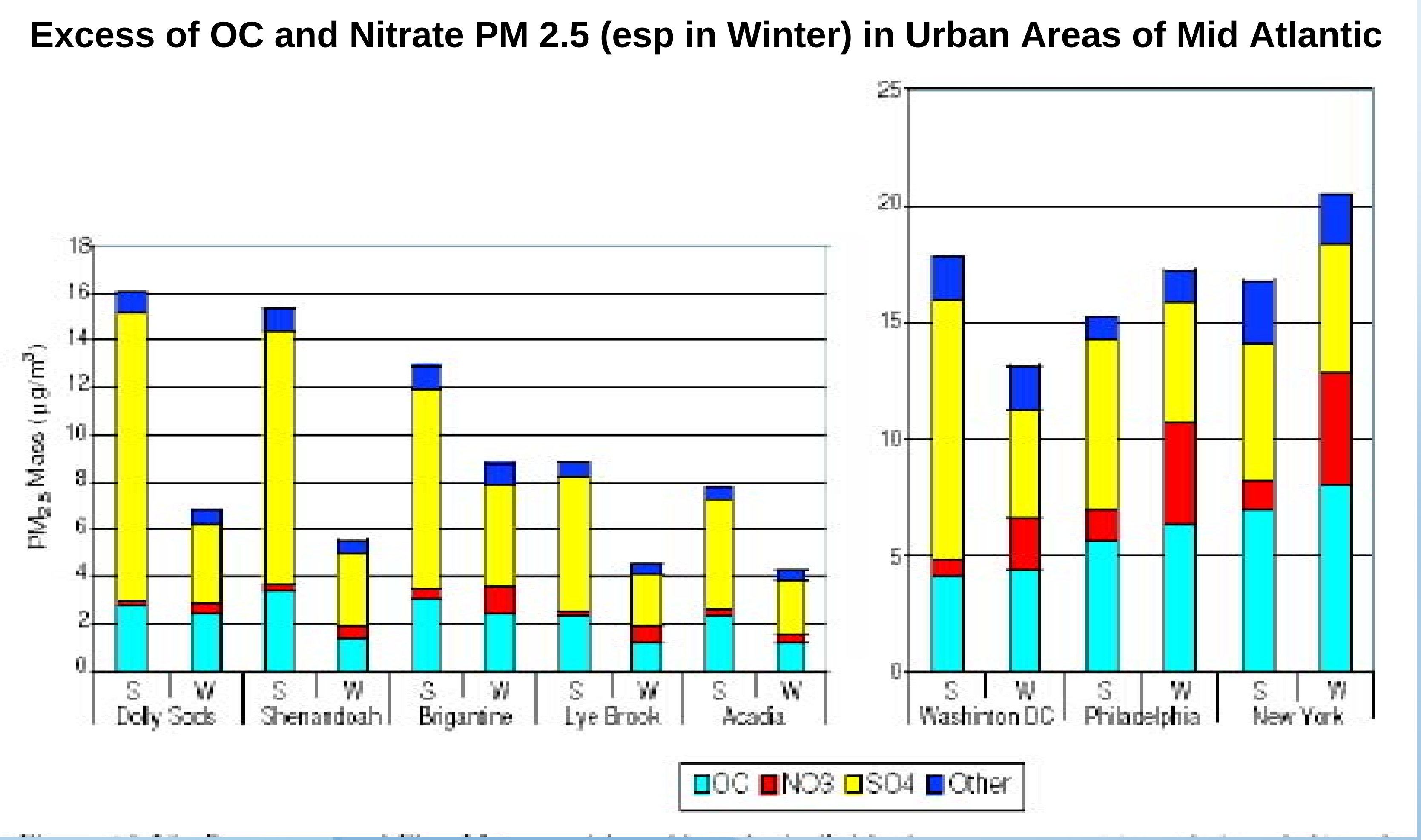


Rural Monitors used for Comparison



This exercise can (and should) be repeated in any area where sufficient data are available.

Urban Excess Concept in Mid-Atlantic



http://www.cambridge.org/us/catalogue/catalogue.asp?isbn=0521842875

How does Ohio's Air Compare to Mid-Atlantic?

- Crustal is <5% in both areas
- Nitrate is low (highest in winter) in both areas
- Both areas are high in both total Carbon and Sulfate
- Varies day-by-day
- Urban Excess analysis for Ohio cities would be useful

What are the Key Source Types Emitting $PM_{2.5}$ and Its Precursors (Nationally)?

2005 Nat'l Emissions (1000 short tons)

Source Category	PM2.5	NH3	NOx	SO2	VOC
FUEL COMB. ELEC. UTIL.	508	27	3,856	10,469	48
FUEL COMB. INDUSTRIAL	178	17	2,042	1,784	152
FUEL COMB. OTHER	421	17	733	578	1,375
CHEMICAL & ALLIED PRODUCT MFG	30	23	70	259	249
METALS PROCESSING	54	3	69	213	46
PETROLEUM & RELATED INDUSTRIES	18	3	354	257	601
OTHER INDUSTRIAL PROCESSES	354	177	429	327	442
SOLVENT UTILIZATION	7	0	7	0	4,278
STORAGE & TRANSPORT	23	1	19	5	1,484
WASTE DISPOSAL & RECYCLING	268	26	111	26	395
HIGHWAY VEHICLES	127	307	6,407	145	4,078
OFF-HIGHWAY	292	3	4,403	516	2,858
MISCELLANEOUS	3,256	3,539	211	135	3,970
TOTAL	5,536	4,143	18,711	14,714	19,976

2005 $PM_{2.5}$ and Precursor Emissions in OHIO

	PM2.5	VOC	NOx	SO2	NH3
Point	66,782	36,637	330,403	1,234,552	5,818
NonPoint	74,509	285,688	41,677	19,904	107,596
Nonroad	9,866	96,859	173,988	15,615	109
Onroad	4,736	171,330	259,301	6,293	11,379
Total	**155,893**	**590,514**	**805,368**	**1,276,364**	**124,902**

* **Wildland Fires not included**

2005 Fugitive Dust $PM_{2.5}$ Emissions in OHIO

	Agricultural Crop Tilling	Unpaved Roads	Paved Roads	Construction
Ohio	22,448	10,086	5,978	7,809
US Total	535,993	840,556	122,436	199,255

2005 Combustion $PM_{2.5}$ Emissions in OHIO

	Agricultural Field Burning	Residential Waste Open Burning	Land Clearing Debris Open Burning	Residential Wood Combustion
Ohio		7,123	3,494	8,937
US Total	224,682	133,639	114,383	381,781

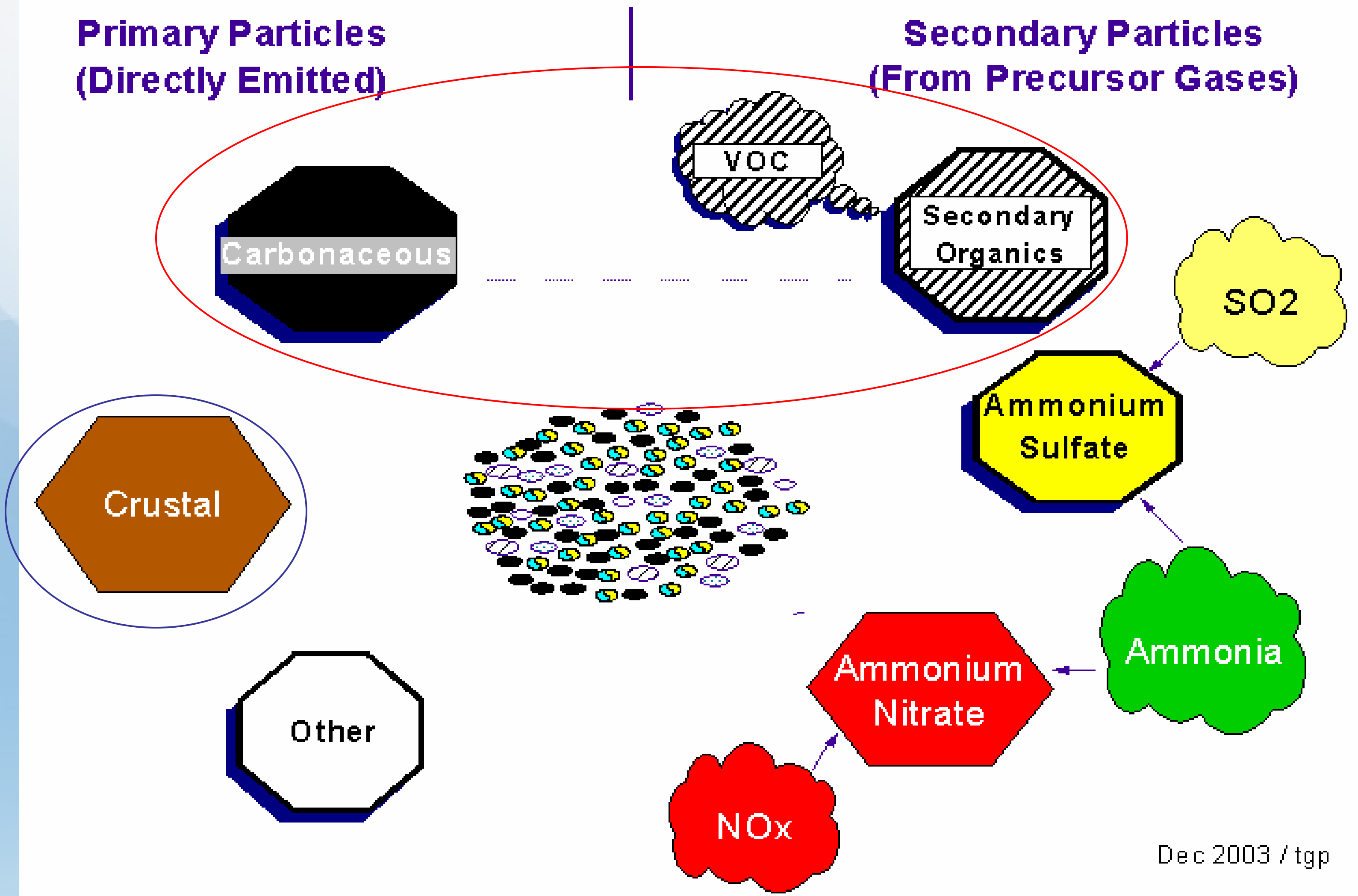
Overview of $PM_{2.5}$ Sources in Midwest

- $PM_{2.5}$ **(OC, EC, SO_2, NOx, Crustal)**
  - **Open Fires** (primary OC, EC, VOC, NO_x & NH_3)
    - Ag & Prescribed fires, open burning, land clearing debris
  - **Motor Vehicles** (NO_x, VOC, OC, EC, NH_3)
  - **Non road emissions** (NO_x, VOC, OC, EC, NH_3)
    - aircraft, agricultural, construction and lawn equipment
  - **Residential Wood Combustion** (OC, EC, VOC)
  - **Boilers** (SO_2, NOx, some crustal, VOC, OC, EC)
  - **Industry** (*Varies:* OC, EC, NOx, SO_2, VOC, crustal)
  - **Fugitive Dust** (mostly crustal, some OC, EC)
    - More ~ Agriculture, anti-skid sanding?
    - Lesser ~ construction, unpaved roads, windblown dust

Miscellaneous $PM_{2.5}$ Precursor Sources

- **Misc VOC Sources** (precursor to secondary OC)
  - household and industrial products, such as paints and varnishes, cleaners, disinfectants, and degreasers
  - Fuel combustion and the handling and distribution of fuel
  - Dairies and other livestock waste
  - Agricultural, Wild & Prescribed fires
- **Misc Ammonia Sources** (precursor to ammonium sulfate and nitrate)
  - during wintertime stagnation, air can be ammonia-rich
  - Livestock wastes from dairies and agricultural operations
  - Wild & Prescribed fires
  - Mobile sources

Let's Talk More About Crustal and Carbon



Speciation of Crustal Component of $PM_{2.5}$

- "Speciation" ~ process of estimating the components of the sample, e.g., crustal from the chemical characteristics of the sample.
- For an ambient or source sample, crustal is the sum of earth oxides:

Crustal% = C1∗Al% + C2∗Ca% + C3∗Si% +C4∗Fe% + C5∗Ti%

Al%, Ca%, Si%, Fe% & Ti% ~ the % of the PM2.5 sample that is Al, Ca, etc, and

C1 – C5 account for Oxygen in the Oxides

- *Speciation is done on both Emissions and Ambient samples*
- *More about emissions speciation in Lesson 6*

Carbonaceous Material – “Matter”

- Ratio OC to EC differs by source type
  - Mobile Sources Gas: 5 - 15
  - Mobile Sources Diesel: 0.4
  - Open Fires: 10 - 12
  - Residential Wood Burning: 7 - 8
  - Fugitive Dust: 15 - 25


Hannaford 2009

Organic Carbon “Matter” (OCM)

- **OC“*Matter*”** includes both the Carbon *and* the O and H that are part of the OC molecule
  - The OC measurement must be “augmented” to account for the “matter”
    - OC * “Augmentation Constant” $\mathbf{C_{Em}}$ **or** $\mathbf{C_{Am}}$
    - Constant differs depending on whether you’re augmenting
      - “fresh” emissions,
      - aerosol after aging and formation of secondary OC, or
      - results of chemical transport and transformation modeling

Organic Carbon “Matter” (OCM) Emissions

- ***Augmentation of Primary (Fresh) Emissions***
  - C_{Em} ~ Emissions Augmentation Constant
  - C_{Em} = 1.2 to 1.8 (depending on source type)
  - C_{Em} applied in Emissions processor

*C_{Em} values in Reff, Bhave, Simon, Pace et al

ES&T 2009 August 1:43(15): 5790-96

Organic Carbon "Matter" (OCM) in Ambient Air

In ambient samples, the $\boldsymbol{C_{Am}}$ can be as high as **2.4**

Why?

- Aerosols Oxidize as they age which adds O and H "matter"

AND

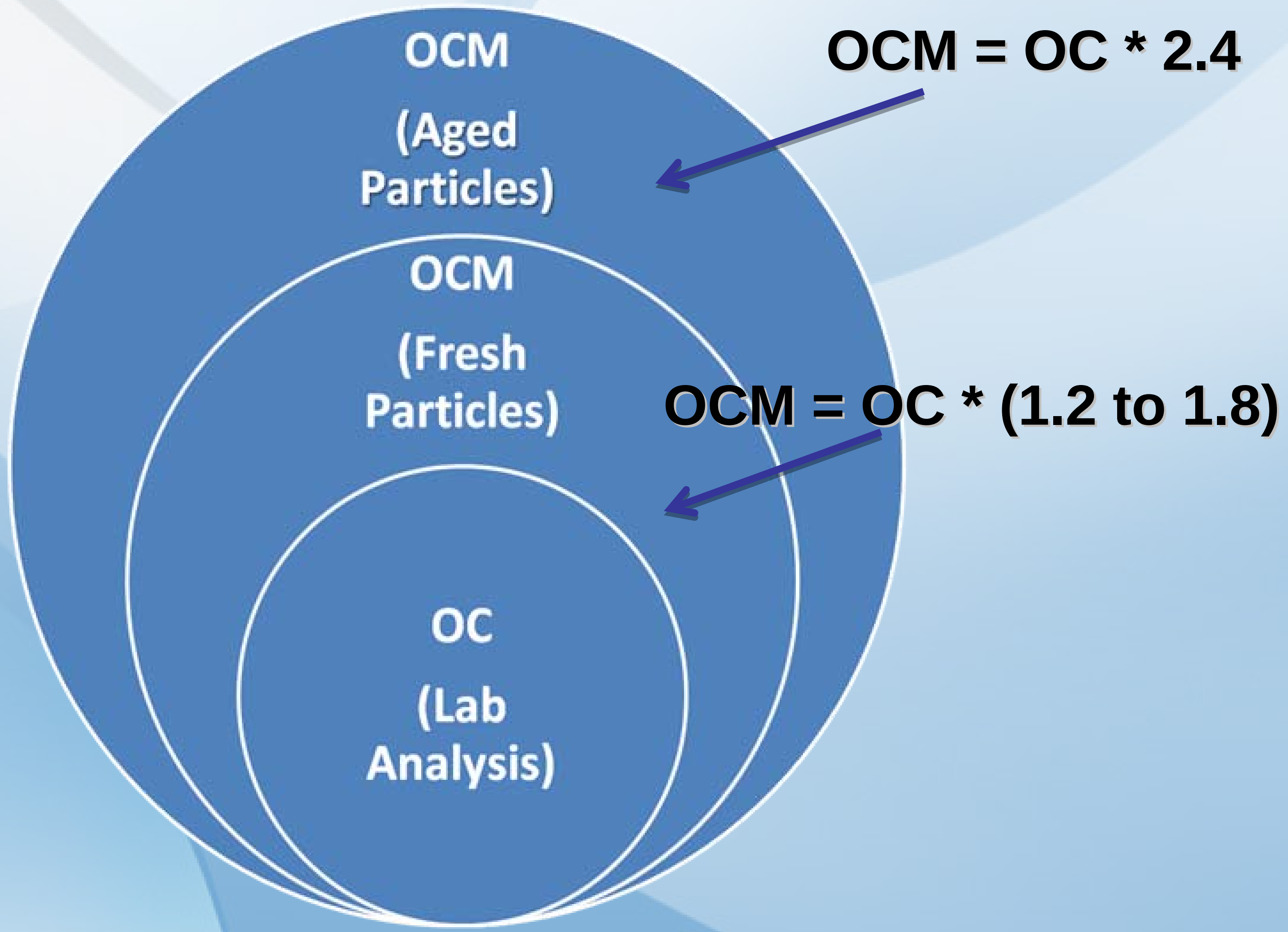
- Secondary OC forms. This secondary OC usually has a high matter content.

Organic Carbon “Matter” (OCM) and Modeling

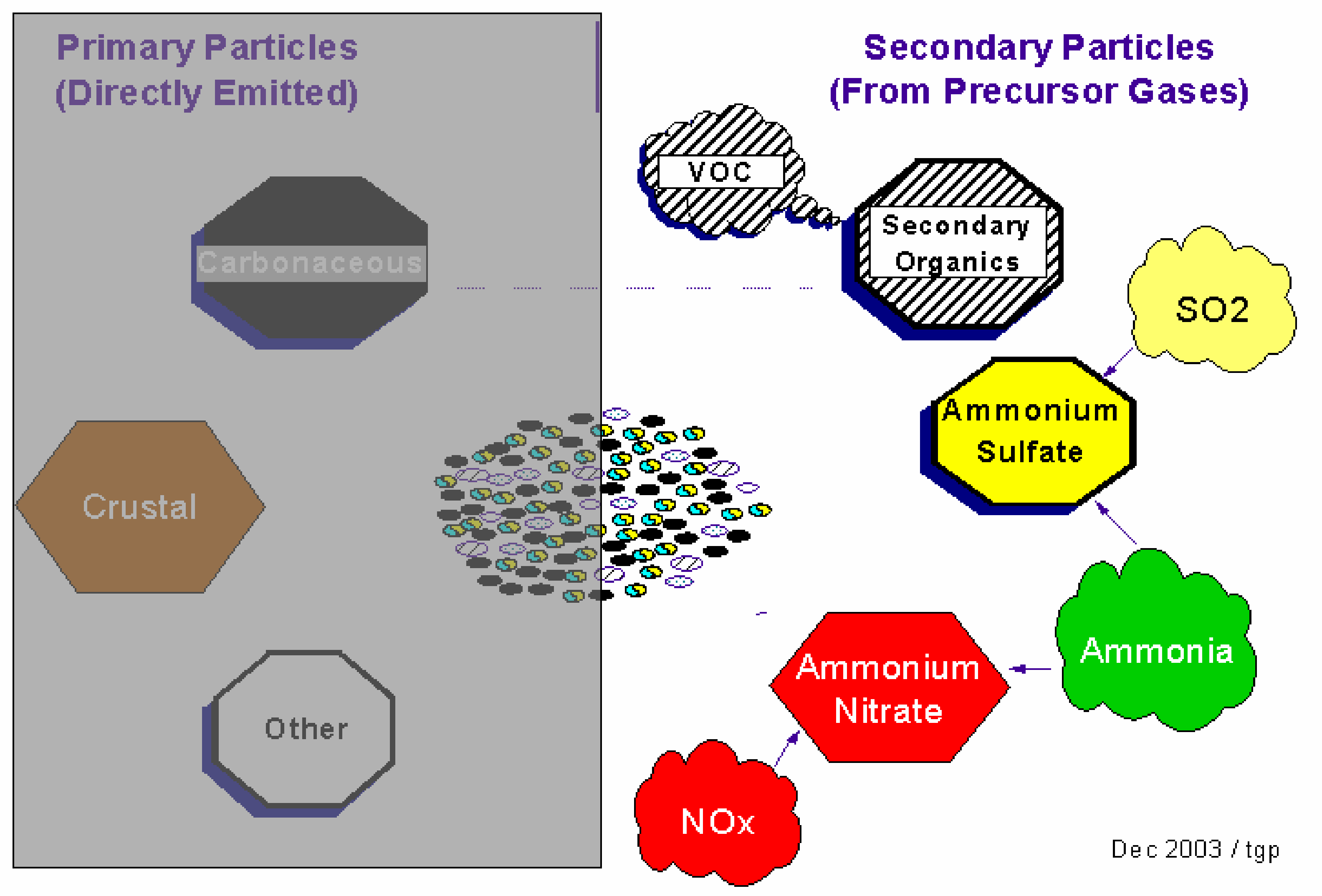
- AQ Models *may* age the aerosols and account for the formation of secondary organic carbon
- They *may* also account for the “matter” (or some of it!)

So – if you’re augmenting modeling results,
Check with the modelers –
Don’t “over-account for the “matter”!

Review of $PM_{2.5}$ Carbon Issues



More About Secondary Formation



Precursor Interactions are Important to Particle Formation

Precursor Interactions

Secondary Organics

- VOC from Vegetation (Terpenes)
  - Relatively fast reaction
- VOC from Mobile Sources (Aromatics)
  - Slower than Terpenes
- Reducing Aromatics >> lower SOA

Ammonium Sulfate

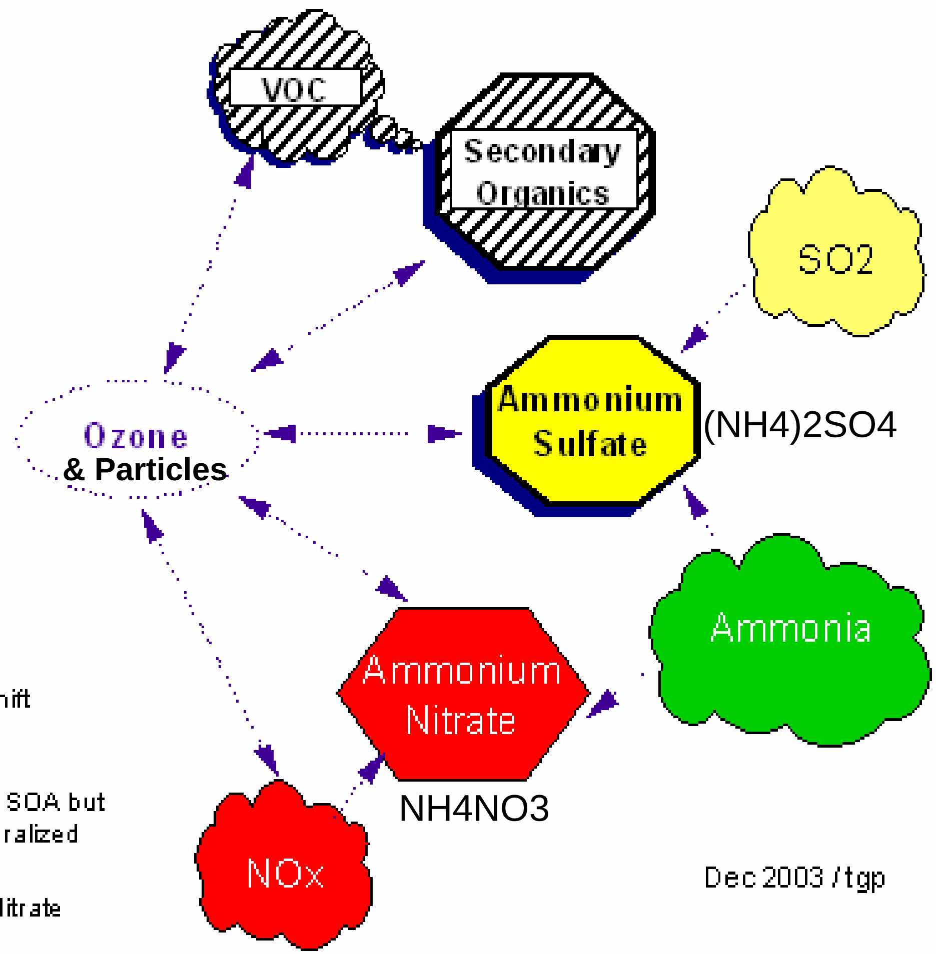
- SO2 from Sulfur in Fuels
- Compared to Ozone:
  - Sulfate forms & deposits more slowly
- If insufficient Ammonia ~
  - Ammonium bisulfate or
- Reducing SO2 >> lower Ammonium Sulfate

Ammonium Nitrate

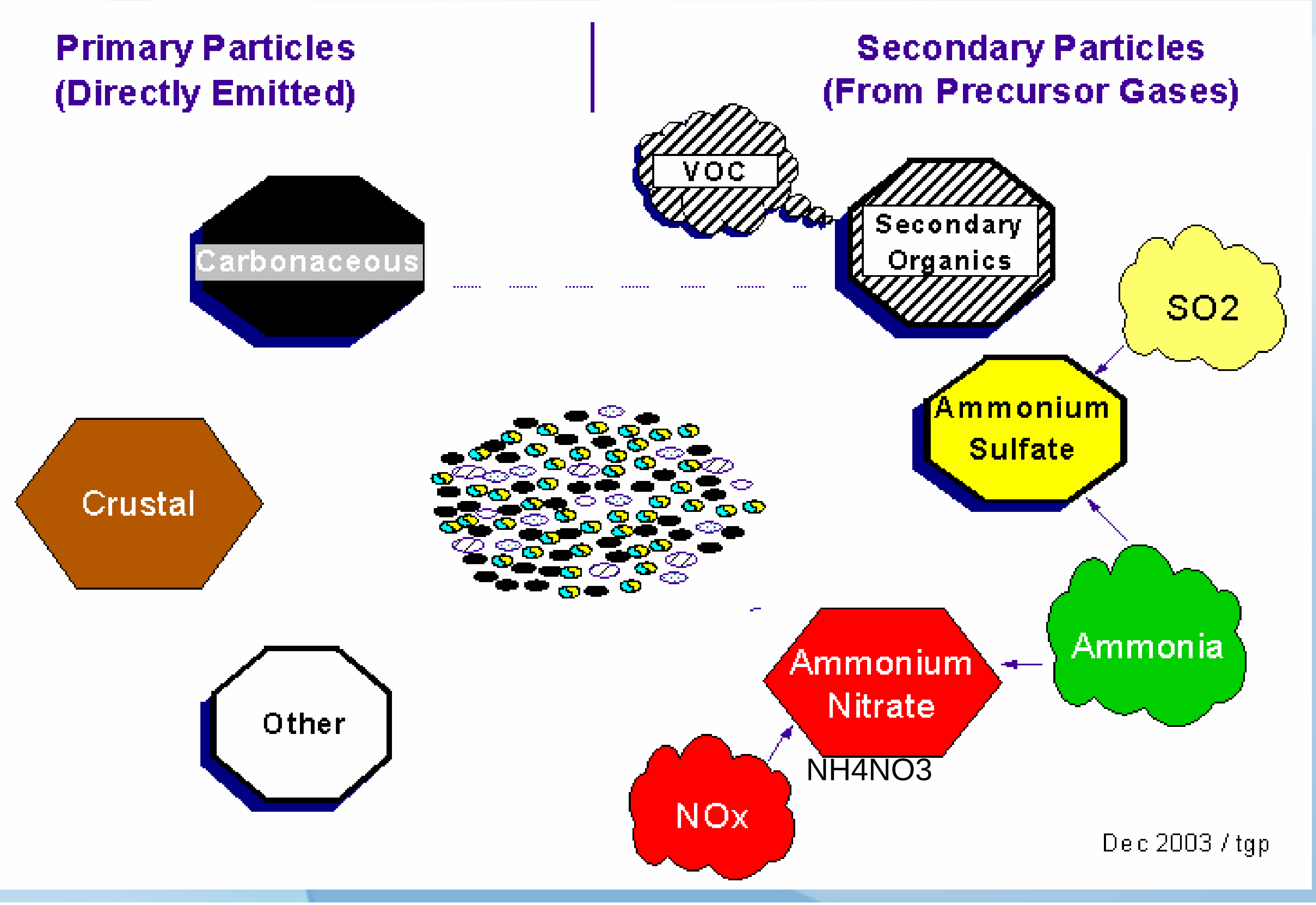
- NOx from fuel combustion
  - Relatively fast reaction
- If insufficient Ammonia ~
  - Sulfate formed before nitrate
- Higher temperatures, lower rH >> Equilibrium shift
  - Less nitrate - more nitric acid
  - Sampling losses
- Reducing NOx may reduce Nitrates, Sulfates & SOA but
  - outcomes very complicated, cannot be generalized

Ozone

- Generally, less Ozone >> less SOA, Sulfate & Nitrate



Review:
$PM_{2.5}$ In Ambient Air - A Complex Mixture



Let's Review and Summarize

- A Complex Mixture
  - Composition
  - Primary vs. Secondary
- Key Sources
  - Composition by source type
  - Directly emitted vs. precursors
- Other Issues
  - Speciation
  - Augmenting to account for "matter" associated with OC

Review of Important $PM_{2.5}$ Source Categories

DIRECT EMISSIONS	PRECURSOR EMISSIONS

Combustion [a, b]

- **Open Burning (all types)**
- **Non-Road & On-Road Mobile**
- **Residential Wood Burning**
- **Wildfires**
- Power Gen
- Boilers (Oil, Gas, Coal)
- Boilers (Wood)

Crustal / Metals [b]

- **Fugitive Dust**
- Mineral Prod Ind
- Ferrous Metals

SO_2 [c]

- **Power Gen (Coal)**
- **Boilers (Coal)**
- Power Gen (Oil)
- Boilers (Oil)
- Industrial Processes

NO_x

- **On-Road Mobile (Gas, Diesel)**
- **Power Gen (Coal)**
- **Non-Road Mobile (Diesel)**
- **Boilers (Gas, Coal)**
- Residential (Gas, Oil)
- Industrial Processes

NH_3

- **On-Road Mobile**
- **Animal Husbandry**
- **Fertilizer Application**
- Wastewater Treatment
- Boilers

VOC [d]

- **Biogenics**
- **Solvent use**
- **On-Road (Gas)**
- Storage and Transport
- Residential Wood
- Petrochemical Industry
- Waste Disposal

a Includes primary organic particles, elemental carbon and condensible organic particles; also some flyash
b Impact of carbonaceous emissions on ambient PM 5 to 10 times more than crustal emissions impact
c Includes SO_2, and SO_3 and H_2SO_4 condensible inorganics
d Contributes to formation of secondary organic aerosols

NOTE: Categories in **BOLD** are most important nationally. Their relative importance varies among and between urban and rural areas.

Questions?

Preparation of Fine Particulate Emissions Inventories

Chapter 2 - The National Emissions Inventory System (EIS) and Emission Inventory Tools

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What Will We Discuss in This Lesson

- Overview of the NEI and Development Schedule
- Key Source Categories for $PM_{2.5}$
- EI Development Tools
- Process-based Emission Models
- Opportunities for SLT Input

The National Emissions Inventory (NEI) and Emissions Inventory System (EIS)?

- **The NEI** is
  - EPA's national database of information on sources of air pollution and their emissions
  - used for analysis, modeling and development of priorities and other improvements
  - has been undergoing several changes that we will address to a limited extent as appropriate
- **The EIS** is
  - EPA's new system for collecting, storing, and accessing the NEI
  - currently available to states to input facility data
  - will be available to accept emissions data input very soon
- Contact: **Solomon.Douglas@EPA.gov** or your EPA Regional Office EI Coordinator

What's Up With The NEI?

- **New – Air Emissions Reporting Requirements** (AERR) 40 CFR Part 51, published December 17, 2008. See Rule at: http://www.epa.gov/ttn/chief/aerr/
  - Changes in reporting schedules and data exchange processes
  - New EPA data system (some element/format changes)
  - Changes in technical requirements, terminologies and procedures – more discussion as this course unfolds
  - $PM_{2.5}$,filterable AND condensible are BOTH required
- For specific details/variations pertaining to your state's data submittal procedures consult with EPA regional office
- Lessons 5 & 6 contain more discussion of the AERR

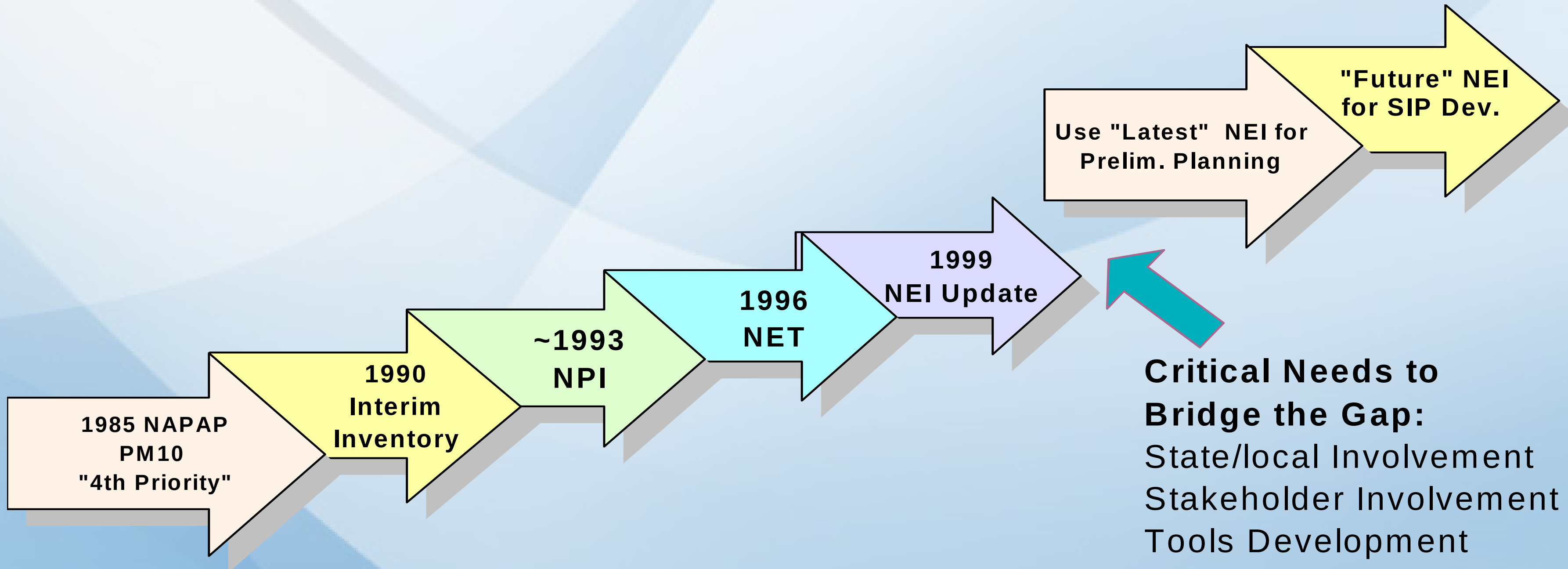
NEI Development Schedule

- 2002 – Former Year of Emphasis (all categories)
- 2005 – Updates for Mobile and Fires
  - Note: Fires were updated each year (2003-2007)
- 2008 – Year of Emphasis (all categories)
  - All data due to EPA by May 31, 2010
- 2011 – Next “cycle” Year of Emphasis
  - Data due by Dec 31, 2012 for CY 2011 and later cycles

Information Included in the NEI

- National tabulation of emissions of PM_{10}, $PM_{2.5}$, SO_2, NO_x, Pb, Ammonia, and VOC
  - Point sources by lat-long: ~52,000 facilities, each containing multiple emission points
    - Over 4,500 types of processes (SCC) represented
  - Area (non-point) & Mobile by County
    - ~400 categories of Highway & Non-Road Mobile
    - Over 300 categories (SCC) of Area sources
- Annual emissions, start/end dates, stack parameters, seasonal emissions
- Also in the NEI
  - HAP emissions for over 6,000 categories of sources (not required by AERR but likely to be - after arduous rule-making process)

Evolution of EPA's National Emission Inventory

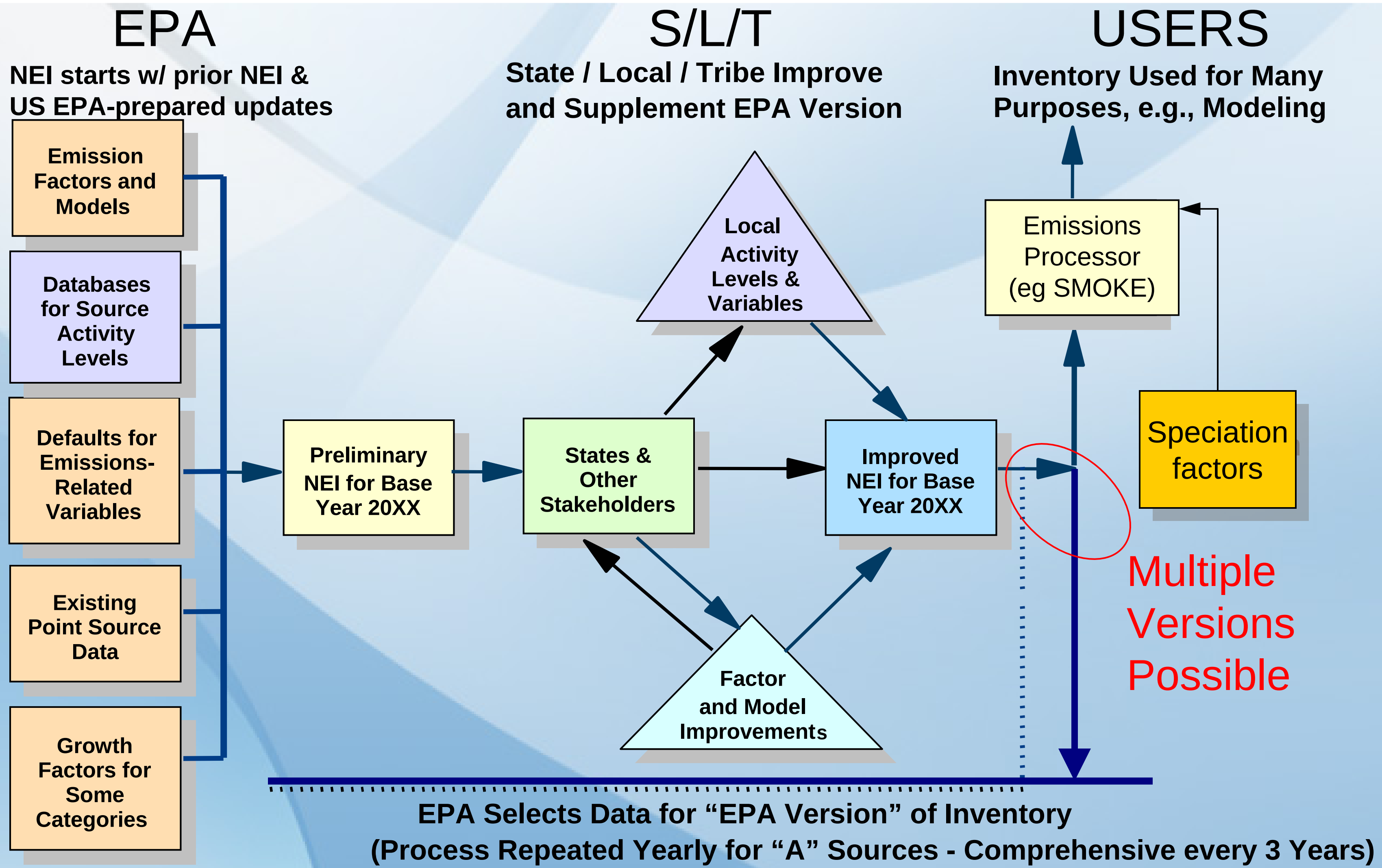


Critical Needs to Bridge the Gap:
State/local Involvement
Stakeholder Involvement
Tools Development

NAPAP - National Acidic Precipitation Assessment Program
NPI National Particulate Inventory
NET National Emission Trends Inventory
NEI Merger of NET and Nat'l Toxics EI

Notes: The NEI will soon be housed in EPA's EIS.
EPA's initial National Inventory was initiated by NEDS in the early 1970's.

NEI Development ~ Cooperative



Typical Source Categories of Primary $PM_{2.5}$ Emissions

- Fugitive Dust Sources (Crustal $PM_{2.5}$)
  - Construction
    - Residential housing, commercial bldgs, roads
  - Mining and quarrying
  - Unpaved and paved roads (incl anti-skid materials)
  - Agricultural tilling
  - Beef cattle feedlots
  - Windblown dust

Note: These categories emit only “filterable” emissions

Typical Source Categories of Primary $PM_{2.5}$ Emissions (cont'd)

- Open Burning Sources (Primary Carbonaceous $PM_{2.5}$)
  - – Structure fires
  - – Agricultural field burning
  - – Open burning
    - Residential municipal solid waste burning
    - Yard waste burning
    - Land clearing debris burning
  - – Wild and prescribed fires

Note: These categories emit both "filterable" and "condensable" emissions

Typical Source Categories of Primary $PM_{2.5}$ Emissions (cont'd)

- External/Internal Fuel Combustion ($Carbonaceous\ PM_{2.5}$):
  - Residential wood combustion
  - Other residential fuel combustion
  - Industrial fuel combustion
  - Commercial/institutional fuel combustion

Note: These categories emit both "filterable" and "condensable" emissions

Typical Source Categories of Primary $PM_{2.5}$ Emissions (cont'd)

- Wildland and Agricultural Fires
  - Prior to 2002
    - Treated as area/nonpoint sources
    - Useless for real planning/impact analysis
  - Beginning in 2002, NEI treats fires as "Events" in time, space
  - Western states were leaders in 2002 NEI upgrade
  - EPA developed new NEI "Events" category
  - More about this in Lesson 9

Typical Source Categories of NH_3 (Precursor) Emissions

- Typical source categories of NH_3 emissions include:
  - Animal husbandry
  - Agricultural fertilizer application (liquid and granulated)
  - Agricultural fertilizer manufacturing
  - Wastewater treatment
  - Autos, Fires

Specific Opportunities for Input from Federal / State / Local / Tribes

- Industrial point source data - search
- Fugitive dust
  - *ONLY IF* important part of strategy

  (Check ambient measurements)
- Residential Open Burning
  - Household waste, yard waste (volumes & burning practices)
  - Regulations & their effectiveness, local surveys of burn activities

Specific Opportunities for Input by Federal / State / Local / Tribes (cont'd)

- Residential Wood Combustion
  - Fireplaces, Wood Stoves
  - local surveys of fuel burned, fireplace vs. wood stoves, wood stove types, local regulations

Specific Opportunities for Input by Federal / State / Local / Tribes (cont'd)

- Construction Debris & Logging Slash
  - Regulations & their effectiveness, local surveys of burn activities
- Wildland and Agricultural Burning
  - Forests, rangeland & especially private & state/ tribal burners
  - (acreages burned, fuel loadings for largest fires, dates, locations)

Questions

Overview: Inventory Preparation Tools

- Activity Data
- Emission Models/Factors
- Process-based Emissions Models
- Spatial Characterization & Location

Inventory Preparation Tools

- **Activity Data**
  – Area source activity data often available
  – But may be in "obscure" local or internet sources- search time needed!
    - Trade Associations
    - Federal Agencies
    - County Gov'ts
- More discussion of the NEI, EIS, CHIEF, AP-42, & Point Source EI Development Tools in Lesson 5

Inventory Preparation Tools (cont'd)

- **Emissions Models**
  - TANKS (VOC only) http://www.epa.gov/ttn/chief/software/tanks/index.html
  - NONROAD http://www.epa.gov/oms/nonrdmdl.htm
  - Ammonia (updated by CMU, UC-Davis and Pechan) http://www.cmu.edu/ammonia/ and http://www.epa.gov/ttn/chief/conference/ei14/session1/mansell_pres.pdf
  - Fires (from Satellites & Recordkeeping) http://www.getbluesky.org/smartfire/ http://www.wrapfets.org/
  - Windblown Dust (under dev by ORD & WRAP) http://www.wrapair.org/forums/dejf/fderosion.html
    - Contact Pierce.Tom@epa.gov

Inventory Preparation Tools (cont'd)

- **Process-based Emission Models**

  "emissions models on steroids"

  – Use realistic location & time relevant values (when possible) for e.g.,
    - wind, temperature
    - RH, vegetation types & moisture
    - soil type & moisture

  – Possible linkages:
    - MM5 &/or Weather Research and Forecast (WRF) model
    - GIS coverages

  – Can estimate emissions "on-the-fly" in Emissions Processor

  – Currently ~ BEIS3 only true process model

Inventory Preparation Tools (cont'd)

- **Process-based Emissions Models (cont'd)**
  - Specific examples (some under development):
    - MOVES (More discussion in Off Road lesson)
    - Fires (More later)
      - Location-specific fuel characteristics
      - Research version estimating fuel moisture
    - Ammonia (under development)
      - temperature-driven release, moisture

Inventory Preparation Tools (cont'd)

- **Process-based Emissions Models (cont'd)**
  - Future Work Expected
    - Fugitive Dust
      - e.g., soil moisture, tilling schedule/type, nearby vegetation
    - Residential Wood Burning
      - Temperature dependence
    - Evaporative Loss
      - Temperature

Inventory Preparation Tools (cont'd)

- **Spatial Characterization & Locator Aids**
  - Satellites
  - Google Earth (GE)
  - Commercial Mapping Software
  - GIS
- **Example use of GE to support NAAQS**
  - Confirmed locations of key Lead point sources
    - Many historically mis-located – ¼ mile to 7000 miles
    - Most locations now reasonably good-fix and lock!
    - Usefulness limited in large facilities
    - Next emphasis on individual stack coordinates
  - Confirmed monitor proximity to major highways

Emissions Processing (EP)

- **Overview**
  - EP's prepare traditional EI (e.g., NEI) for grid models
    - Reformatted
    - Spatially
    - Temporally
    - Chemical species
  - SMOKE

Emissions Processing (cont'd)

- Input
  - "Reformatted" point source EI
  - Mobile Source EI
  - Annual, county-level area source EI
  - Annual point & event data (except for CEM data)
- Outputs
  - Gridded, hourly emissions file
  - EC, OC, SO_4, Nitrates, PM-Other/PM-Fine
  - Model-ready
  - "Factor-driven" manipulation of "input data"

Emissions Processing (cont'd)

- **"Factors" in the Emissions Processor**
  - Spatial Allocation Factors
  - Temporal Allocation Factors
  - Speciation Profiles

Emissions Processing (cont'd)

- **Spatial/Temporal Allocation Factors**
  - County-to-Grid Spatial Allocation Factors
  - Temporal Allocation Profiles (hourly & seasonal)
  - Examples
    - Census tracts
    - Gridded land use
    - Vegetation “coverages”
    - Operating schedules
    - Ambient temperature

Emissions Processing (cont'd)

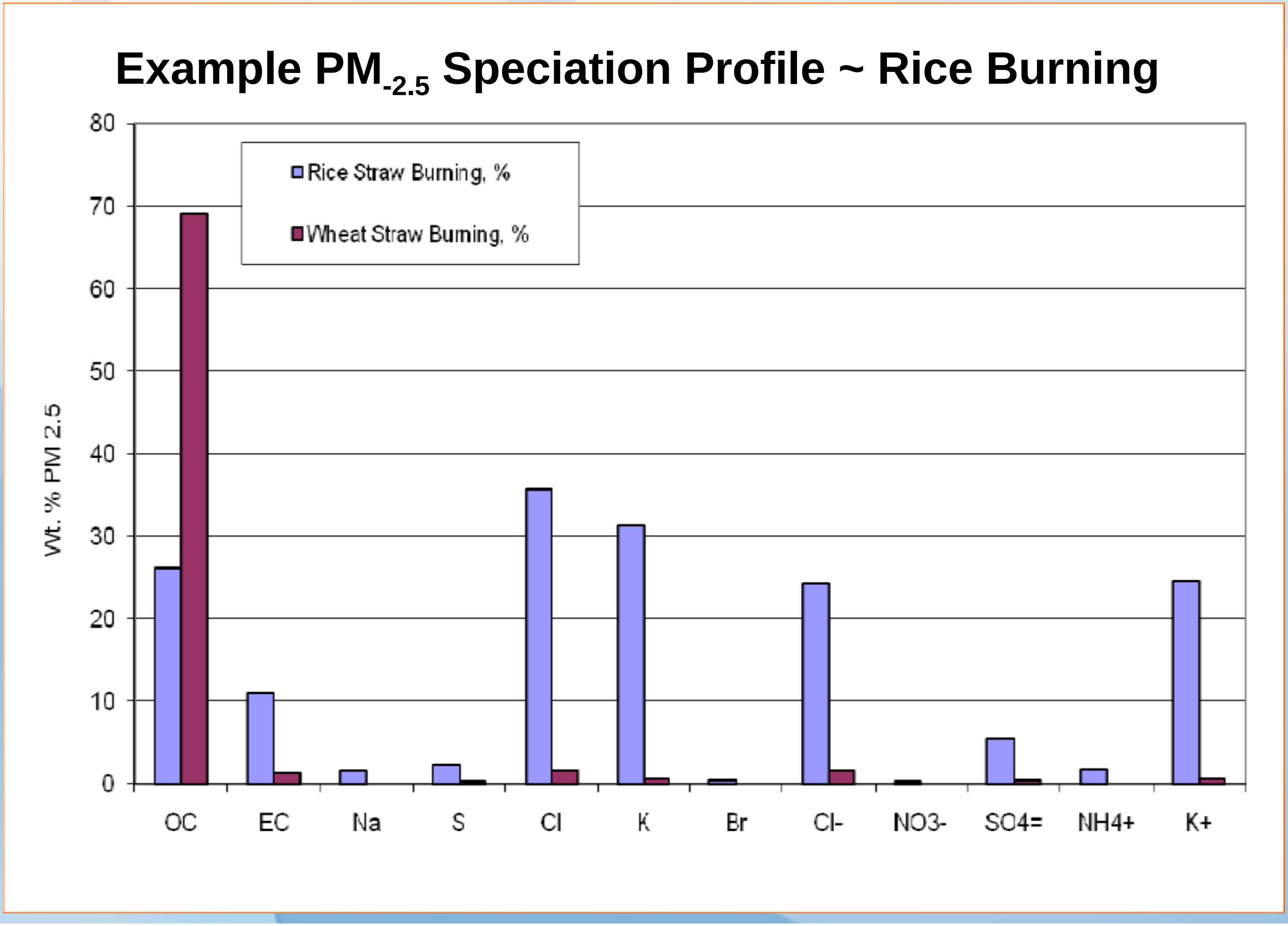
- Speciation Profiles (“factors”)
  - Estimate of the EC, OC, “OC Matter,” SO_4, NO_3, and Crustal portions of each $PM_{2.5}$ source’s emissions
  - All $PM_{2.5}$ sources assigned to 1 of ~ 70 “profiles”
  - Note: Species composition of $PM_{2.5}$ is stored with modeling files, NOT in the NEI
  - Species profiles recently updated (Reff et al)
    - Reff.Adam@epa.gov
- Speciate 4.2
  - Basis of Species profiles
  - Update by E.H. Pechan & Associates, Inc.
  - http://www.epa.gov/ttn/chief/conference/ei18/session5/divita.pdf

Emissions Processing (cont'd)

- **What is SPECIATE?**
  - An EI Tool that derives OCM, EC and Crustal from $PM_{2.5}$
  - Database of emissions profiles by species for each of ~ 70 source categories
    - Includes metals, ions, elements, organic and inorganic compounds, in consistent units
  - Three categories in SPECIATE:
    - Particulate matter (PM), VOC, Other gases

    (e.g., Hg, NO/NO_2/HONO, semi-volatile organics)
  - Microsoft Access database
  - Periodic updates
  - http://projects.pechan.com/ttn/speciate4.2/
  - Contact: beck.lee@EPA.Gov

Emissions Processing (cont'd)



PECHAN
E.H. Pechan & Associates, Inc.

Summary

- The NEI
  - How it started, what is in it, how it is developed, tools
- NEI depends on local input
  - Very important for some categories
- "Local opportunities" to improve the EI
- Process-based Emissions Models
  - More accurate, especially for daily EI
- Emissions Processing
  - Making the EI "model ready"

Questions?

Preparation of Fine Particulate Emissions Inventories

Chapter 3 – Onroad Mobile Sources

PECHAN
E.H. Pechan & Associates, Inc.

EPA's Onroad Models – Overview

- MOBILE6
  - Current official model for SIP emission inventory development
- NMIM
  - Incorporates MOBILE6
  - VMT is an input to model
  - Can be used to calculate emission inventory, not just emission factors
- MOVES
  - Significant departure from MOBILE model series
  - Released in draft form April 2009
  - Not acceptable for SIP inventories until final version is released by end of 2009

MOBILE6 Overview

- Use MOBILE6 model for emission factors
  - $PM_{2.5}$, SO_2, NO_x, NH_3, PM_{10}, VOC, and CO
  - $PM_{2.5}$ and PM_{10} emission factors are for primary emissions ($PM_{2.5}$-PRI and PM_{10}-PRI)
- Use VMT data for activity
- Map VMT data to corresponding MOBILE6 emission factors

MOBILE6 Modeling Inputs

- PM inventories are annual
  - Contrasts with seasonal ozone or CO inventories
- MOBILE6 runs should represent multiple seasons
  - Generally either 12 sets of monthly inputs or 3 to 4 sets of seasonal inputs
- Some MOBILE6 inputs will be same as those used for ozone or CO modeling:
  - Registration distribution
  - Control programs

MOBILE6 Modeling Inputs (cont'd)

- Some data needs to correspond to month/season being modeled
  - Ambient conditions
  - Fuel parameters
  - Speeds/speed distributions (may not change by season)
  - VMT mix (may not change by season)
- $PM_{2.5}$ emission factors fairly insensitive
  - No temperature or speed correction factors applied in MOBILE6
  - No deterioration with age in PM emission factors

MOBILE6 Modeling Inputs (cont'd)

- Additional data required for PM modeling in MOBILE6
  - Diesel sulfur content (in parts per million [ppm])
- Additional commands needed for MOBILE6
  - Described in MOBILE6 User's Guide
- $PM_{2.5}$ and PM_{10} emission factors cannot be calculated in same scenario – particle size must be specified in each scenario

National Mobile Inventory Model (NMIM)

- Creates emission inventories at the national level or for any combination of states/counties
- Consolidated emissions modeling system
- Combines a graphical user interface, MOBILE6, NONROAD, and a county database
- Database contains most recent information used in the NEI

National Mobile Inventory Model (NMIM) (cont'd)

- Calculates criteria pollutants and HAP emissions (whereas MOBILE6 only calculates emission factors)
- All estimates based on same input parameters
- Used to generate 2002, 2005, and draft 2008 NEI
- Optional for states
- Available for general use in 2004
- Produces same results as MOBILE6 and NONROAD

Sources of VMT Data

- State Department of Transportation
- Metropolitan Planning Organization
- 2002/2005 NEI VMT Data based on:
  - State-provided VMT
  - FHWA HPMS data summaries
    - By roadway type and State
    - By roadway type and Urban Area
    - Nationally by Vehicle Type

VMT Approach

- Distributions of VMT by roadway type, vehicle type, by hour of day can be applied directly to VMT or included within MOBILE6 input files
- Also need to have speeds matched to roadway types either as average speeds or as speed distributions by speed ranges

Level of Detail of VMT Data

- By county
- By roadway type (or link level)
- By vehicle type
- Appropriate time period

Calculating Onroad Emissions

- Match VMT to corresponding MOBILE6 emission factor
  - Map according to speed, roadway type (RT), vehicle TYPE (VT), time period
- $\text{Emis} = \text{VMT} \ast \text{EF} \ast \text{K}$
  - Emis = emissions in tons by RT, VT
  - VMT = vehicle miles traveled on RT by VT in miles
  - EF = emission factor in grams/mile by RT, VT
  - K = conversion factor

MOVES

- MOVES is a completely new model
  - New data, structure, capabilities
  - New fleet and activity defaults
  - Updated emission rates based on recent test data
- Significant PM testing of light-duty gas vehicles through Kansas City Study 2004-2005
  - 496 light-duty gas cars and trucks tested from model years 1968-2005
  - Vehicles tested in summer and winter conditions
  - Results of study indicate that MOBILE6 underestimated PM, particularly at cold temps

Preparing for MOVES

- Can be run at a national, county, or project level of detail
- Converters and importers available with draft MOVES2009
  - Can be used to convert MOBILE6 inputs to MOVES-formatted data (e.g., for age-based registration distributions) in near-term
  - For long-term use, states should collect data that better maps to MOVES

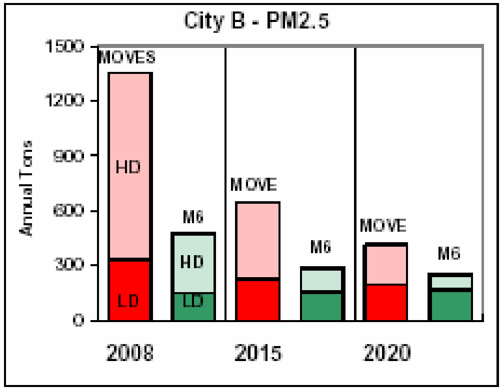
Preparing for MOVES

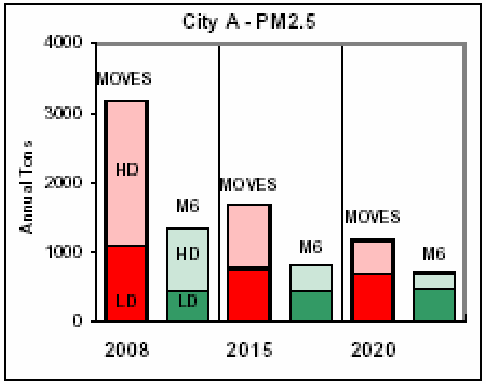
- National trends
  - PM emissions substantially higher than MOBILE6
  - NO_x emissions generally higher than MOBILE6
  - HC, CO emissions similar to or lower than MOBILE6
- Local inputs important
  - Fleet mix, fuels, activity
  - Temperature significantly affects PM

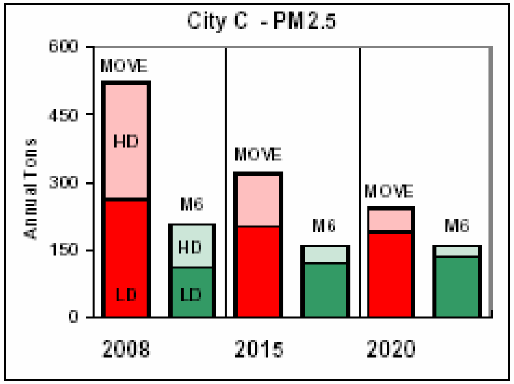
City-Specific $PM_{2.5}$ Emissions

$PM_{2.5}$

- Kansas City program found high gas PM emissions esp. at cold temps
- New analysis of heavy trucks shows higher deterioration than MOBILE6
- MOVES accounts for impact of vehicle speed – MOBILE did not

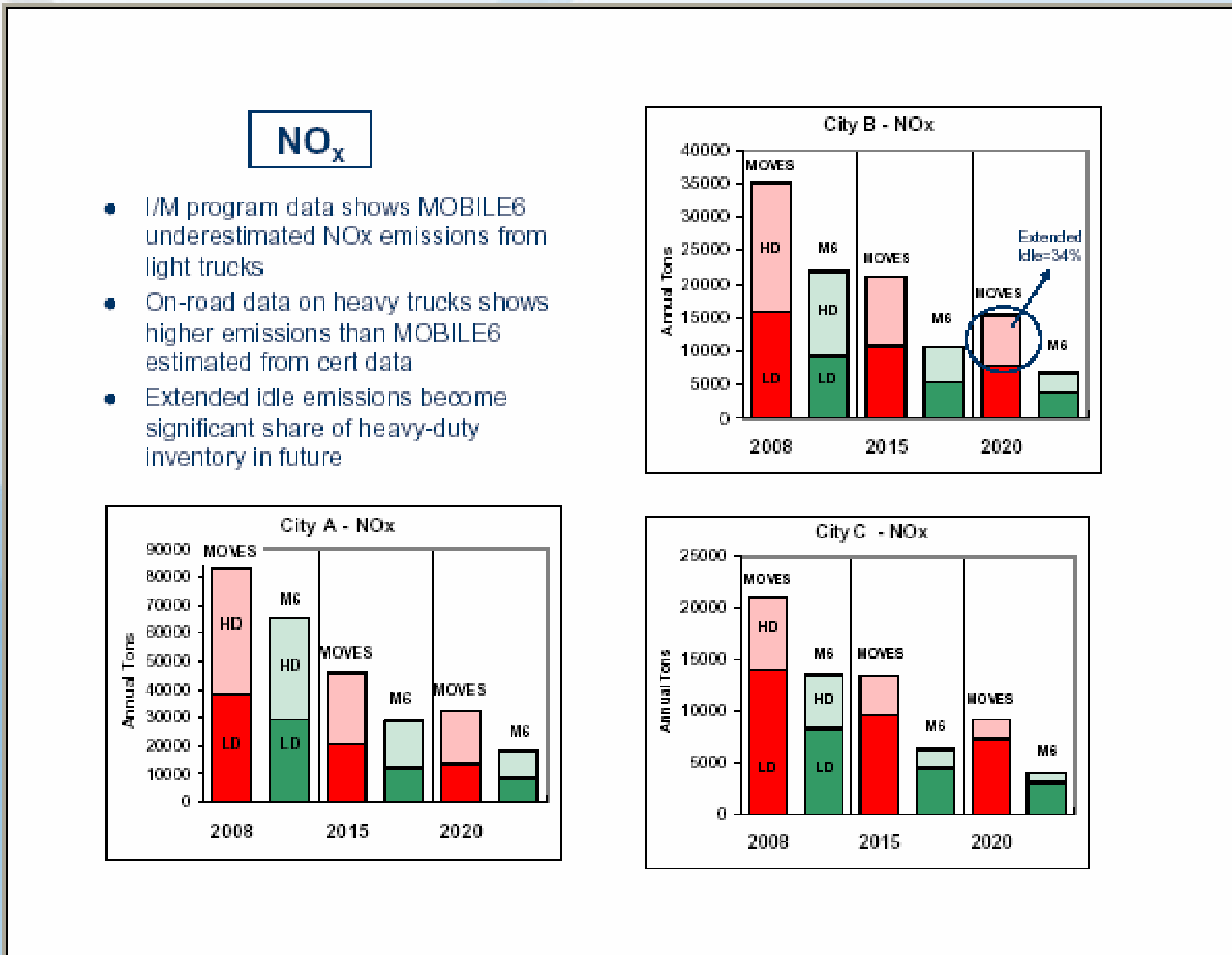






Source: EPA, 2009

City-Specific NO_x Emissions

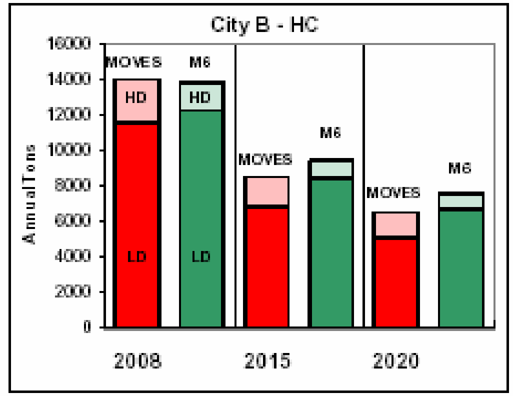


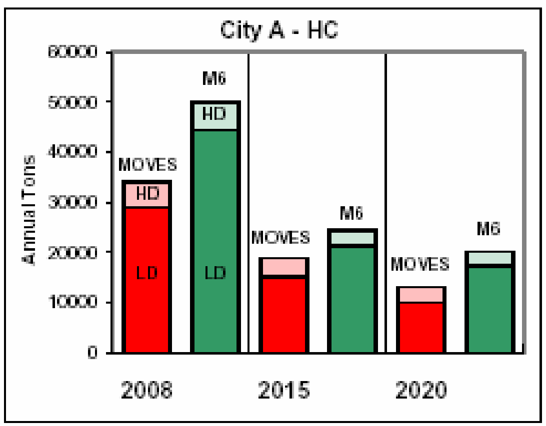
Source: EPA, 2009

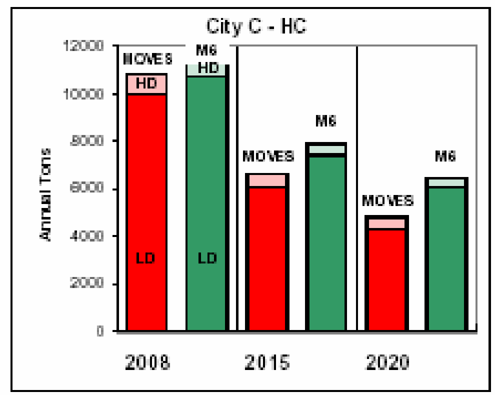
City-Specific HC Emissions

HC

- I/M program data shows MOBILE6 overestimated HC emissions from newer technology cars
- Evaporative emissions on newer technology vehicles very low; re-evaluating leak emissions for final model







Source: EPA, 2009

MOVES Schedule

- Draft MOVES2009 released April 2009
  - No official uses for this model
- Official MOVES2009 to be released by end of 2009
  - Use will be required for
    - Next round of SIPs (due 2012 and 2013)
    - Regional conformity analysis following conformity grace period of 3-24 months
    - Project level conformity following grace period
    - NEPA analysis (e.g., air toxics)

Additional Resources

- MOBILE6 website: http://www.epa.gov/otaq/m6.htm
- MOVES website: http://www.epa.gov/otaq/models/moves/index.htm

Preparation of Fine Particulate Emissions Inventories

Chapter 4 – Nonroad Mobile Sources

PECHAN
E.H. Pechan & Associates, Inc.

Nonroad Mobile - Overview

- Nonroad Categories Addressed
  - Engines included in EPA's NONROAD model
  - Aircraft
  - Commercial Marine Vessels
  - Locomotives

NONROAD Model - Overview

- EPA's NONROAD Model
  - Emission Estimation Model for Most Types of Nonroad Engines
  - Differentiated by Equipment Type and Other Characteristics
  - Past, Present and Future Year Inventories
  - Stand Alone *(No User Data Necessary)*

NONROAD Model – Overview (cont'd)

SCCs (4-digit SCC denotes engine type)

2260xxxxxx	2-Stroke Gasoline
2265xxxxxx	4-Stroke Gasoline
2267xxxxxx	Liquefied Petroleum Gasoline (LPG)
2268xxxxxx	Compressed Natural Gas (CNG)
2270xxxxxx	Diesel

Two exceptions:

2282xxxxxx	Recreational Marine
2285xxxxxx	Railroad Maintenance

NONROAD Model – Overview (cont'd)

Equipment Category (7-digit SCC denotes equipment)

- Airport ground support
- Agricultural
- Construction
- Industrial
- Commercial
- Residential/commercial
- Lawn and garden
- Logging
- Recreational marine vessels
- Recreational equipment
- Oil field
- Underground mining
- Railway maintenance

10-digit SCC generally denotes specific application within equipment category

NONROAD Model – Overview (cont'd)

- Pollutants
  - PM_{10}-PRI, $PM_{2.5}$-PRI, CO, NO_x, VOC, SO_2, and CO_2
    - PM_{10} and $PM_{2.5}$ emission factors represent Primary PM
    - NH_3 not a direct output of NONROAD, can be estimated based on fuel consumption and EPA emission factors derived from light-duty onroad vehicle emission measurements
    - Model estimates exhaust and evaporative VOC components

NONROAD Model Emission Equation

$$I_{exh} = E_{exh} * A * L * P * N$$

where:

I_{exh}	=	Exhaust emissions, (ton/year)
E_{exh}	=	Exhaust emission factor, (ton/hp-hr)
A	=	Equipment activity, (hours/year)
L	=	Load factor, (proportion of rated power used on average basis)
P	=	Average rated power for modeled engines, (hp)
N	=	Equipment population

NONROAD Model - Emission Equation (cont'd)

- Emission Factors
  - Dependent on engine type and horsepower
    - Future year emission controls or standards reflected in emission factor value
  - PM_{10} assumed to be equivalent to total PM
    - For gasoline engines, $PM_{2.5} = 0.92 * PM_{10}$
    - For diesel engines, $PM_{2.5} = 0.97 * PM_{10}$
    - For LPG and CNG-fueled engines, $PM_{2.5} = PM_{10}$
  - SO_2, CO_2, and evaporative VOC emissions based on fuel consumption

Geographic Allocation

- County-level allocation of equipment population
  - National or state-level equipment populations from PSR or alternate sources, reported by equipment type (SCC) and horsepower range
  - Allocates populations to counties using surrogate indicators that correlate with nonroad activity for specific equipment types

Temporal Allocation

- NONROAD accounts for temporal variations in activity
  – Monthly activity profiles by equipment category according to 10 geographic regions
  – Typical weekday and weekend day activity profiles by equipment category; do not vary by region

Relation of NONROAD to National Mobile Inventory Model (NMIM)

- NMIM2008 incorporates NONROAD2008
  - Common pollutant inventories produced by each (i.e., HC, CO, CO_2, NO_x, PM, and SO_2) will be the same, provided the same inputs are used
- Unlike NONROAD2008, NMIM includes default county temperature and fuel data in a single database
- Additional pollutants in NMIM include ammonia, HAPs, among others
- Use NONROAD2008 if equipment populations, fuel consumption estimates, or output by model year required

Improving Inputs

- Specify local fuel characteristics and ambient temperatures
- Replace NONROAD model default activity inputs with state or local inputs
  - Perform local survey
- Obtain local information to improve geographic allocation indicators and temporal profiles

Improving Inputs (cont'd)

- Significant PM Fine Equipment Categories include:
  - – Diesel construction
  - – Diesel farm
  - – Diesel industrial
  - – Gasoline lawn and garden
  - – Gasoline recreational marine

Resources

- http://www.epa.gov/otaq/nonrdmdl.htm
- From this web site, there are links to:
  - Downloadable version of NONROAD2008 model
  - Documentation
    - User's Guide
    - Technical Reports to describe the sources and development of all model default input values

AIRCRAFT - Overview

- SCCs
  - 2275020000 – Commercial Aircraft
  - 2275050000 – General Aviation
  - 2275060000 – Air Taxis
  - 2275001000 – Military Aircraft
- Activity Data – landing and take-off operations (LTOs)
- Emission Factors – aircraft/engine-specific or fleet average

AIRCRAFT - Overview (cont'd)

- Definitions of Aircraft Categories:
  - Commercial - Aircraft used for scheduled service to transport passengers, freight, or both
  - Air taxis - Smaller aircraft operating on a more limited basis to transport passengers and freight
  - General aviation - aircraft used on an unscheduled basis for recreational flying, personal transportation, and other activities, including business travel
  - Military aircraft - aircraft used to support military operations

AIRCRAFT - Overview (cont'd)

- Aircraft operations are defined by landing and take-off operation (LTO) cycles, consisting of five specific modes:
  - Approach
  - Taxi/idle-in
  - Taxi/idle-out
  - Take-off
  - Climb-out
- The operation time in each of these modes (TIM) is dependent on the aircraft category, local meteorological conditions, and airport operational considerations

COMMERCIAL AIRCRAFT - NEI Method

- Activity/Emissions Developed at Airport Level
  - Commercial Aircraft Activity
    - LTO data based in part on departures by aircraft type collected by Bureau of Transportation Statistics for U.S. carriers operating nonstop between domestic airports
      - T-100 Segment Data
    - LTO data reported by FAA for smaller commercial airports are also used and reconciled with T-100 data to avoid double counting

COMMERCIAL AIRCRAFT - NEI Method (cont'd)

- Activity/Emissions Developed at Airport Level
  - Commercial Aircraft Emissions
    - Emissions calculated using airport-level LTO data by aircraft type and emission rates from FAA's Emissions and Dispersion Modeling System (EDMS) Version 5.1.
    - Used default engines for each aircraft type and default time-in-mode values.
  - EPA also using EDMS to estimate aircraft ground support equipment (GSE) and auxiliary power units
    - Will subtract out aircraft GSE from the NONROAD model estimates

COMMERCIAL AIRCRAFT - NEI Method (cont'd)

- EDMS5.1 estimates both PM_{10} and $PM_{2.5}$ emissions
  - Based on International Civil Aviation Organization's (ICAO) First Order Approximation, version 3.0
- Represents substantial enhancements over previous PM estimation methods

General Aviation and Air Taxi – NEI Method

- National Emissions for General Aviation and Air Taxis are calculated using equation:

$$\textit{National Emissions}_{c,p} = \textit{National LTOs}_{c} * EF_{c,p}$$

where:	*LTOs*	=	landing and take-off operations
	EF	=	emission factor
	c	=	aircraft category
	p	=	criteria pollutant

- EPA not currently estimating emissions for Military Aircraft

General Aviation and Air Taxi – NEI Method (cont'd)

- National Emissions Allocation

$$\textit{Airport Emissions}_{c,p,x} = \textit{National Emissions}_{c,p} * AF_{c,p,x}$$

where: AF = allocation factor

x = airport (e.g., La Guardia)

c = aircraft category

p = criteria pollutant

$$AF_{c,x} = \textit{LTOs}_{c,x} / \textit{National LTOs}_{c}$$

General Aviation and Air Taxi – NEI Method (cont'd)

- EPA developing a nationwide lead (Pb) emissions inventory from in-flight aircraft
  - In-flight emissions occur outside the landing and take-off cycle (above 3,000 feet)
- Lead (Pb) emissions
  - Associated with General Aviation and Air Taxi categories
  - National aviation gas lead inventory allocated to airports based on percentage of piston-engine operations at each airport

AIRCRAFT - NEI Method (cont'd)

- Airport level emissions can now be reported as point source emissions associated with the airport's latitude and longitude coordinates
- Some airport locations may have more than one facility in the facility inventory

AIRCRAFT - NEI Method (cont'd)

- Information on the procedures used to develop criteria pollutant (as well as HAP) aircraft emission estimates will be made available at:

  http://www.epa.gov/ttn/chief/eiinformation.html

AIRCRAFT - General Approach

- Determine the mixing height to be used to define the LTO cycle
- Define the fleet make-up for each airport
- Determine airport activity in terms of the number of LTOs by aircraft/engine type
- Select emission factors for each engine model associated with the aircraft fleet

AIRCRAFT - General Approach (cont'd)

- Estimate the time-in-mode (TIM) for the aircraft fleet at each airport
- Calculate emissions based on aircraft LTOs, emission factors for each aircraft engine model, and estimated aircraft TIM
- Aggregate the emissions across aircraft

COMMERCIAL AIRCRAFT - Improvements to NEI

- Review the commercial airport data for representativeness
- Determine engine types associated with local aircraft types, to replace default aircraft/engine assignments in EDMS
- Obtain information on climb-out, takeoff, approach times, as well as taxi/idle times

GA, AT and Military Aircraft - Improvements to NEI

- Obtain local estimates of LTOs for these categories (to obtain LTOs not covered by FAA data)
- Obtain information on the aircraft/engine types that comprise the aircraft fleet for these categories
- Apply EPA engine-specific emission factors or EDMS
- Include latitude/longitude of the airport

COMMERCIAL MARINE VESSELS - Overview

- Commercial Marine Vessel SCCs
  - 2280002100 – Diesel, In Port
  - 2280002200 – Diesel, Underway
  - 2280003100 – Residual, In Port
  - 2280003200 – Residual, Underway
- Diesel CMV consist of Category 1 and 2 engines
- Residual CMV (steamships) consist of larger Category 3 engines

COMMERCIAL MARINE VESSELS - Overview

$$Emissions = Pop * HP * LF * ACT * EF$$

where: Pop = Vessel Population or Ship Calls

HP = Average Power (hp)

LF = Load Factor (fraction of available power)

ACT = Activity (hrs)

EF = Emission Factor (g/hp-hr)

COMMERCIAL MARINE VESSELS NEI Method – Category 1 & 2 CMV

- National diesel emissions split into near-shore port and underway components
  - Per EPA SIP guidance, 75% of all diesel fuel consumed in port
- Underway activity assigned to counties using ton-mile weighting factors developed from Bureau of Transportation Statistics GIS data
- Port emissions assigned to 150 largest ports using port traffic data per *Waterborne Commerce of the U.S.*
  - Port emissions then assigned to a single county

COMMERCIAL MARINE VESSELS NEI Method – Category 3 CMV

- Near port emissions based on two 1999 EPA studies:
  - *Commercial Marine Activity for Deep Sea Ports in the United States*
  - *Commercial Marine Activity for Great Lake and Inland River Ports in the United States*
- These studies provide detailed activity profiles for typical ports, and provide method to extrapolate detailed time-in-mode activity data from a select typical port to another similar port

COMMERCIAL MARINE VESSELS
NEI Method – Category 3 CMV

- Emission inventories developed for 117 ports for each mode of operation, including hotelling, maneuvering, reduced-speed zone, and cruising
- Auxiliary engine and propulsion engine emissions estimated separately
- Spatial allocation performed using GIS shapefiles to specify the geographic locations for each type of near port emissions
  - Hotelling and maneuvering emissions were assigned to the port point
  - Reduced-speed zone and cruise mode emissions were allocated to lines representing shipping lanes

COMMERCIAL MARINE VESSELS NEI Method – CMV

- EPA developing a GIS shape file library using BTS data to better allocate Category 1 & 2 port emissions to counties, and also to better allocate underway emissions to line segments/counties
- EPA also developing an offshore Federal waters CMV inventory, including emissions from ~2-10 miles, up to 200 miles offshore

COMMERCIAL MARINE VESSELS - Emission Factors

- Emission factors available on a horsepower-hours basis
- EPA developing updated emission rates
  - As part of Category 3 Marine Diesel Rule
  - Recently coordinating with ARB and European studies
- $PM_{2.5}$-PRI = 0.92 * PM_{10}-PRI emissions

COMMERCIAL MARINE VESSELS - Emission Factors (cont'd)

- PM_{10}-PRI EFs for Category 1 and Category 2 Engines:

Engine Category	PM_{10} [g/kW-hr]
Category 1: <0.9 liters/cylinder	0.54
Category 1: 0.9 - 1.2 l/cyl	0.47
Category 1: 1.2 - 2.5 l/cyl	0.34
Category 1: 2.5 – 5.0 l/cyl	0.30
Category 2 (5 - 30 l/cyl)	0.32

COMMERCIAL MARINE VESSELS - Emission Factors (cont'd)

- PM_{10}-PRI EFs for Category 3 Engines (> 30 l/cylinder):

Engine: Vessel Type	PM10 [g/kW-hr]
Propulsion: All Vessel Types	1.4
Auxiliary Engine: Passenger	1.3
Auxiliary Engine: Other Ocean-Going Vessels	1.1

- Values representative of West Coast Ports – other US ports have slightly higher PM emission rates due to higher sulfur levels in residual oil
- Low-load adjustments factors developed by pollutant
  - Emission factor constant to about 20% load – below that, emissions increase as the load decreases

COMMERCIAL MARINE VESSELS - NEI Method (cont'd)

- Procedures documentation for criteria pollutant and HAP commercial marine emission estimates for Category 1 and 2 vessels available at:
  - ftp://ftp.epa.gov/EmisInventory/2002finalnei/documentation/mobile/2002nei_mobile_nonroad_methods.pdf.
- For Category 3 vessels, see:
  - ftp://ftp.epa.gov/EmisInventory/2005_nei/mobile/commercial_marine_vessels_2002__and_2005.pdf.

COMMERCIAL MARINE VESSELS - Improvements to NEI

- Review 2008 NEI emission estimates for representativeness
- Allocate port emissions to ports other than 150 largest
- Obtain activity estimates at the local or state-level from Department of Transportation, Port Authority

COMMERCIAL MARINE VESSELS - Improvements to NEI (cont'd)

- Local CMV Study Needs
  - Fuel consumption
  - Categories of vessels
  - Number and size (hp) of vessels in each category
  - Number of hours at each time-in-mode
    - Cruising
    - Reduced speed zone
    - Maneuvering
    - Hotelling

LOCOMOTIVES - Overview

- SCCs:
  - 2285002006 – Diesel Class I Line Haul
  - 2285002007 – Diesel Class II/III Line Haul
  - 2285002008 – Diesel Passenger (Amtrak)
  - 2285002009 – Diesel Commuter
  - 2285002010 – Diesel Switchyard Locomotives

LOCOMOTIVES - Overview (cont'd)

- EPA not developing default locomotive emission estimates for 2008 NEI
- States are encouraged to submit both activity and emissions
- Class I line-haul locomotives account for ~80 percent of fuel of all rail operations

LOCOMOTIVES - Class I Line Haul Methods

- Emissions calculated by multiplying the amount of fuel consumed by emission factors
- Fuel consumption for inventory area estimated by dividing traffic density expressed in gross tons miles (GTM) by system-wide fuel consumption index (GTM/gal)
  - Traffic Density (GTM) can be obtained directly from the individual railroads or from Association of American Railroads
  - Fuel consumption index calculated by dividing the system-wide gross ton miles (GTM) by the system-wide fuel consumption (gal)
  - Adjustments can be applied to account for grade and train type

LOCOMOTIVES - Class I Line Haul Methods - ERTAC

- Eastern Research Technical Advisory Committee (ERTAC) working to develop a railroad emissions inventory
- ERTAC Proposed Method
  - Use Federal Railroad Administration's GIS data to construct link-level million gross tons per mile (MGT) data
  - Combined with Fuel Consumption Index, calculate link-based fuel consumption to better reflect how GTM are actually concentrated across rail line route miles
- Limitation of link-level activity data
  - Confidentiality issues
  - Some MGT data represent multiple railroad links

LOCOMOTIVES - Class I Line Haul Methods - ERTAC

- Emission factors calculated by railroad carrier to reflect system-wide fleet mix
- Activity applied to emission factors to estimate link-level emissions by pollutant
- Emissions can be easily aggregated to either the county or state level

LOCOMOTIVES - Other Line Haul

- Class II and Class III Line-haul
  - Obtain estimates of system-wide fuel consumption for these railroads
  - Allocate to counties based on track mileage, as freight density typically not available
  - If fuel data not available, may estimate fuel by applying average fuel consumption factors to annual carload-mile data

LOCOMOTIVES - Other Line Haul (cont'd)

- Commuter and Passenger Rail
  - Obtain estimates of system-wide fuel consumption for these rail lines
  - Allocate to counties based on estimates of train-miles traveled
    - Calculated by county using the number of trains, schedule for each train, and length of the route traveled
  - Account for rail lines that operate only electric cars for their entire route or for portions of their route

LOCOMOTIVES - Rail Yards

- Rail yard methodologies
  - Estimate portion of total Class I fuel consumption used for switching operations
  - For a given rail yard, apply emission factors or fuel consumption to the number of switchers in operation, adjusting for operating less than 24 hours per day, 7 days per week
- For the 2008 NEI, states encouraged to report rail yard emissions as point sources

LOCOMOTIVES - Emission Factors

- Year 2008 Fleet Average Emission Factors
  - Line Haul PM_{10} Emission Factors
    - Class I: 12.05 lbs PM_{10}/thousand gallon
    - Class II/III: 10.35 lbs PM_{10}/thousand gallon
  - Rail Yard PM_{10} Emission Factors
    - 16.49 lbs PM_{10}/thousand gallon
    - 0.53 tons PM_{10}/yard locomotive
  - $PM_{2.5} = 0.97 * PM_{10}$

LOCOMOTIVES - Resources

- Revised Inventory Guidance for Locomotive Emissions, SESARM, May 2004

  http://www.metro4-sesarm.org/pubs/railroad/FinalGuidance.pdf

- Eastern Regional Technical Advisory Committee (ERTAC)

  http://www.ertacrail.info/erjoomla/

LOCOMOTIVES - Case Study - Overview

- Case Study: County-level Locomotive Inventory for Sedgwick County, KS
  - See Case Study Number 4-1

LOCOMOTIVES - Case Study – Solution

- Case Study: County-level Locomotive Inventory for Sedgwick County, KS
  - See Handout 4-1

Preparation of Fine Particulate Emissions Inventories

Chapter 5 – Point Source Inventory Development & Reporting

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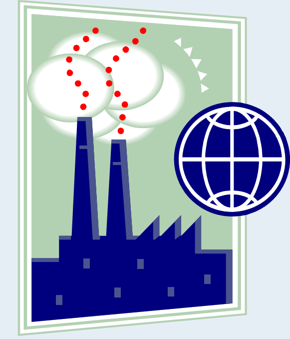
Point Source Session - Objectives



- Define terms and authorities
- Talk about NIF, state needs (e.g., permits, fees, compliance etc.), SIPs and interfaces
- Identify major point sources that contribute to $PM_{2.5}$
- Emphasize how $PM_{2.5}$ inventory is not complete w/o other pollutants that cause secondary particles to form
- Discuss experiences in other states and how they can provide guidance

What Authorities Require the Inventory?

- **The Clean Air Act, as amended 1990** (Section 110/SIPS and others)
  - Delegations from EPA to states
- The **Air Emissions Reporting Rule** - AERR (40 CFR Part 51) published December 2008 http://www.epa.gov/ttn/chief/aerr/
- State Program Needs & Rules

  - State Implementation Plans – a joint state/Federal mechanism to plan for compliance with ambient air quality standards (NAAQS) of $PM_{2.5}$, in this case
  - State permitting and compliance statutes and rules

How Do We & EPA Define a Point Source? (of $PM_{2.5}$ SO_2, VOC, NO_x, or NH_3 Emissions)

- Traditionally, any emission source that was included in an inventory as an individual entry has been considered a **point** source, as opposed to an **area** (now nonpoint) source. Various changes have now resulted in the latest "paraphrased" (for NIF) in the AERR shown on the next slide.

How Do We & EPA Define a Point Source? (of $PM_{2.5}$ SO_2, VOC, NO_x, or NH_3 Emissions) (cont'd)

- Sources now, starting with the CY 2008 inventory, per AERR, actual emissions are to be reported as **point sources**, if they meet the criteria as a **major source (i.e., Title V- PTE)** under 40 CFR part 70 for CO, VOC, NO_x, SO_2, $PM_{2.5}$, PM_{10}, lead, or NH_3 (excluding HAPs) during the inventory year. States may continue to include smaller (minor) sources, reporting them (all) every third year. This change is envisioned to facilitate better tracking of changes in source emissions, shutdowns, and start-ups over time and result in a more stable universe of reporting point sources, and facilitate eliminating overlaps and gaps in estimating point source and **non-point (area)** source emissions.

How Do We & EPA Define a Point Source?
(of $PM_{2.5}$ SO_2, NO_x, VOC or NH_3 Emissions) (cont'd)

- **Thus**, AERR defines point sources simplistically, to be **Title V** sources and all the smaller facilities that the state chooses to include (being wise to include Synthetic Minors, if possible). Submit majors annually.
- Plant emissions for PM_{10}, $PM_{2.5}$, SO_2, VOC, NO_x, and NH_3 are all important for deciding what sources to include in your point source inventory for $PM_{2.5}$

Roles of Point Source Emissions Data

- Title V fees are normally based on reported actual emissions – a source of program revenue
- A complete point source inventory provides a compliance/enforcement tool - a major point of program unity and common data
- A means of accepting, storing, and analyzing data that satisfy state and Federal reporting requirements
- Necessary for uniform SIPs for haze and for individual pollutant inventories for prioritization, modeling, and other planning or tracking functions
- Same basic facility information as Greenhouse Gas inventory/registry; Toxics Release Inventory and programs for other media – uniform and in one place

Data Collection Process From Facilities

- Historically, special surveys were a major means to collect facility data
- Evolution of inventory practice and technologies have integrated facility data reporting with web-based or other means for facilities to efficiently report directly into agencies data systems with states providing review and approval functions
- Distinctions for annual reporting for major facilities and lesser for smaller facilities

U.S. VOC Emission Estimates by Year (thousands of tons)

Sector	1990	2000	2010*
EGU	35	41	43
Non-EGU Point	2,609	1,441	1,493
Nonpoint	11,678	8,544	8,516
Nonroad	2,666	2,565	1,875
On-Road Vehicle	9,328	5,246	2,601
Total	**26,317**	**17,839**	**14,530**

***EPA Projections**

U.S. NO_x Emission Estimates by Year (thousands of tons)

Sector	1990	2000	2010
EGU	6,411	4,494	2,307
Non-EGU Point	3,134	2,278	1,976
Nonpoint	4,801	3,886	3,678
Nonroad	2,068	2,092	1,634
On-Road Vehicle	9,536	8,074	4,290
Total	**25,951**	**20,825**	**13,887**

U.S. SO_2 Emission Estimates by Year (thousands of tons)

Sector	1990	2000	2010
EGU	15,832	10,819	6,366
Non-EGU Point	4,293	2,199	2,167
Nonpoint	2,470	1,875	1,878
Nonroad	163	177	17
On-Road Vehicle	500	254	30
Total	**23,260**	**15,326**	**10,459**

Point Sources of NH_3 Emissions

- Industrial NH_3 emissions can be placed into three broad categories related to the nature of the emissions source:
  - Emissions from industrial processes (such as fertilizer manufacturing)
  - Use of NH_3 as a reagent in NO_x control
  - Refrigeration losses
- Tonnage-wise the numbers are relatively small
- Facilities and government have little experience in reporting ammonia because of historical needs/requirements
- Agricultural emissions (generally nonpoint) will be discussed in a separate lesson

Point Sources of NH_3 Emissions (cont'd)

- Examples of other specific industrial processes that likely emit NH_3 include:
  - Combustion sources with ammonia injection for control of NO_x – likely EGU
  - Ammonium nitrate & ammonium phosphate fertilizer production
  - Petroleum refining
  - Pulp and paper production
  - Beet sugar production
- These industrial processes also are reported with significant emissions in the Toxics Release Inventory (TRI)

When Does EPA/AERR Require Submittals?

- Point sources (major) for CY 2008 (+2009, 2010) due by May 31, 2010 (+2011 & 2012)
  - NO_x SIP Call included in AERR applies only to identified Eastern states
- Subsequent (CY 2011+) submittals (including mobile and non-point) are due to EPA within 12 months of the end of the inventory year (i.e., 2011 due on or before Dec 31, 2012) – may be shortened later
- States must also report summer day emissions of VOC and NO_x from point sources on an annual basis for summer day emissions of NO_x from any point source for which the state specified control measures in its SIP
  - NO_x SIP Call requirements in AERR not applicable to Western states

Other Related NEI Changes

- **New data elements** for contact name, contact phone, emission type, emission release point type, and MAD* codes now required for reporting point source and nonpoint emissions (*defined on a later slide)
- States must **report their ID codes** for facility, unit, process and stack
- **EPA will assign EIS Identifier codes** when data are added to the NEI

New Required NIF Data Elements per AERR

- Contact name – “lead” contact at facility
  – assumed to be manager or technical contact
- Contact phone – # of person above
- Emission type – a code
  – describing the temporal period of emissions reported (year, day, etc.)
- Emission release point type – a code to
  – describe the physical emission release point (vertical, horizontal, fugitive, etc.)
- And Method Accuracy Data (MAD) codes
  – horizontal reference datum, horizontal accuracy measure, reference point, source map scale and coordinate data source for location reference data

Cross-Media Electronic Reporting Regulation - CROMERR

- Not addressed in AERR but necessary to address
- Intended to increase the transparency and integrity of electronically submitted data submitted by facilities for <u>any media</u> and to retain submitted data through all "transportation steps" to EPA
- Difficult to establish electronically after the fact - May be a hindrance to efficient flow of data due to the "headache" level - Work carefully w/IT personnel if you have electronic submittal - Paper <u>may</u> be "safe," bureaucratically speaking
- New NIF system promised to be "CROMERR Compliant"

Other NEI/NIF/AERR Related Changes

- XML & CDX – not for this audience necessarily, but need to talk to IT folks
- Relate to languages, procedures and means of submittal data to EPA via state and EPA "Nodes"
- Not all states have yet developed their nodes – process still in transition/flux in some states
- However, you cannot meet the requirements until these IT hurdles are understood and overcome – or gotten around

Resources for Identifying Point Sources of $PM_{2.5}$ and NH_3

- EIIP Point Source Guidance (Volume II)
- AP-42 (further discussion later)
- Existing Inventories
  - NEI for previous years
  - SIP submittals
  - Toxics Release Inventory (TRI) for NH_3
- Agency Field Inspectors – these resource individuals typically know how a particular facility works and what is emitted – Talk to them and Listen!

Point Sources of Filterable versus Condensable Emissions - Review

- Combustion sources emit both filterable and condensable PM emissions
  - Boilers, refinery processes (e.g., crackers)
  - Furnaces, kilns, metallurgical processes, etc.
  - IC engines (reciprocating or turbines)
- Fugitive <u>dust</u> sources emit filterable emissions only
  - Storage piles, roadways, agricultural, etc.
  - Unpaved/unpaved roads at industrial sites
- Fugitive <u>process</u> – can emit either/both

Primary vs. Secondary PM - Review

- **Primary PM** is directly emitted and the ambient air - sum of filterable and condensable should be reported in total and/or by parts – follow conventions carefully to avoid double counting-use correct codes
- **Secondary PM** is formed through ambient chemical reactions downwind
  - Precursors include SO_2, NO_x, NH_3, and VOC (VOC may also be part of primary)
  - Precursors should be reported as normal part of reporting process
  - Secondary should **NOT** be included in inventory

Testing for Factors Basic Points

- Stack Testing with probe/filter & maybe a sizing impactor system for filterable only – add means to cool for condensables
- Particle-size analysis/distributions of PM-FIL (e.g., AP-42 Factors) – proportion total by size and mass of particles
- Analysis of metals and organics can be done reliably and fairly economically

Other Important PM Terminology – Review- Filterable vs. Condensable AND Secondary

- Filterable PM (as caught on a Modified Method 5 filter or other) are directly emitted
  - Solid and/or liquid
  - Captured on single filter - impinger catch typically not included unless including as condensables
  - All particles w/no separation between PM_{10} and $PM_{2.5}$
- Condensable PM exists in vapor phase at stack conditions (Method 202, and OTM 28)
  - Forms solid or liquid particles, immediately upon cooling
  - EPA considers to always be $PM_{2.5}$ or less

Test Methods that Quantify Total $PM_{2.5}$

- **Proposed EPA Method 201A (OTM 27) - When stack gas < 85°F, Before Filtration**
- **Proposed EPA Method 202 (OTM 28)** – also includes condensable portion
  - Not yet official method – early in 2010, perhaps
  - Uses widely available hardware
  - Nitrogen purge added to old 202 are different - to reduce sulfate artifact
  - Very minor cost increase from existing Method 202
  - **EPA encourages use** even thought not yet official
- **Analysis** for organic carbon compounds and black carbon can be done via generally available and accepted methods at slight increase in cost

Other Test Methods that Quantify Total $PM_{2.5}$ Including Condensables in Stacks

- **Available, but generally unused-dilution methods**
  - Have been accepted method for mobile sources since 1970’s
  - Expensive, cumbersome and require very skilled and experienced test crews
  - Limited availability of hardware
  - Use of this equipment may produce better data from only a limited class of sources
  - Not official EPA test methods – not sure if/when
  - **Analysis** for organic carbon compounds and black carbon can be done via generally available and accepted methods

What to Report to EPA

- $PM_{2.5}$-PRI (and/or $PM_{2.5}$- FIL & PM-CON individually)
  - Note that all PM-CON is assumed to be $PM_{2.5}$ size fraction
- Continue to report PM_{10}-PRI (and/or PM_{10}-FIL & PM-CON individually)
- **QA:** PM_{10}-CON and $PM_{2.5}$-CON should be the same for the same source, and any $PM_{2.5}$ value should NEVER be greater than the corresponding reported value for the PM_{10} counterpart – If a part is greater than the whole, you have made an error

Reminders/Checks

- Use the NIF 3.0 PM pollutant code extensions that identify the forms of PM (i.e., -PRI, -FIL, or -CON)
- Verify the form of the PM:
  - Emission factors or tests you use to estimate emissions; and
  - PM emissions facilities report to you
- Update your database management system to correctly match and report with the specific pollutant codes in NIF 3.0

AP-42 Particle Size Data for Estimation Purposes – Review

- Based on very generalized data
- AP-42 Appendix B-1 and Appendix B-2 should be used only for developing a general sense of (filterable) particle size of emissions
  - Some rare cases of condensable data included, probably with artifacts (i.e., original Method 5 w/ impingers)
  - Evaluate any such data used carefully relative to the specific source of concern, especially for condensed particles

AP-42 Particle Size Data (cont'd)

- AP-42 - http://www.epa.gov/ttn/chief/ including data references cited, are often not clear on source test and analysis methods used to develop particle size and factor input data
  - See background documents for AP-42 chapters for details
  - Very little specific $PM_{2.5}$ testing and data are available, and it may be several years before a fully adequate database is established for general estimation purposes, especially for condensable emission sources

Factor Information REtrieval (FIRE) Database-Review

- Latest version available is on EPA's CHIEF pages of TTN http://www.epa.gov/ttn/chief/software/index.html
- Caution - contains many unevaluated and un-rated data/references – not automatically recommended w/o further evaluation
- Currently updated to:
  - Incorporate most revisions to date of AP-42
  - Add more PM_{10}-FIL, PM_{25}-FIL, and PM-CON emission factors, as available
- Watch for more updates

PM Calculator - Not Recommended

- From Earlier Lesson-
  - Formerly EPA supported but not now
  - Guess at best

Summary of Available $PM_{2.5}$ Emission Factors/Tools

- Good Recommended Factors - Few and None (test methods, lack of funds, lack of requirements for full range of testing, etc.) – load shift to states/industry
- Little EPA Parametric Testing to Develop a quality Emission Factor Database –
  - Development VERY limited with many uncertainties
  - Will take time to build
- Meanwhile, you are encouraged to
  - Test (or require facilities and/or trade groups to test)
  - Participate in planning or review of the tests and data, and use latest most acceptable test methods and analysis
  - Adopt EPA format for reporting test data and submit when review and acceptance of data are complete. Share!

Point & Nonpoint Source Overlap Issues

- For categories included in both point and non-point (area) EIs:
  - Subtract total point activity from total state activity to obtain total area activity – where available

Total Nonpoint Activity = Total Activity – Σ Total Point Activity

- Example for Fuel Combustion Sources:
  - Point activity: fuel throughput from point source EI survey
  - Total activity: fuel throughput from state/local gov. agencies or U.S. DOE/EIA State Energy Data reports

Point & Nonpoint Source Overlap Issues (cont'd)

- QA/QC Results
  - Review county-level area/non-point source estimates for reasonableness
  - Make adjustments based on experience of agency's personnel
  - If your state's point EI includes sources w/emissions below the AERR point threshold, sum & include the emissions in the area/non-point EI – do not double count
  - Work on GHG inventories and registries will overlap to some extent (combustion)

Bottom Line

- Point source emissions are dominated by a few large facilities such as EGU, paper, etc. Others can be important, however – individually or collectively
- Most criteria pollutants (and GHG) are involved either as primary or secondary precursors
- NIF/AEER, CROMERR, etc., changes need to be studied, absorbed, and incorporated into inventory plans
- Coordinate closely with Permits, Compliance, and others in state/local agencies, especially those who inspect and have intimate familiarity with facilities
- Know and coordinate with your IT folks closely re CDX, XML, node details, etc. – long before due
- Involve your facilities from the beginning and use means available to get them to test to get <u>real</u> data
- Good luck!

Reading List

- ***Stationary Source Control Techniques Document for Fine Particulate Matter***, EPA/OAQPS, Oct. 1998 http://www.epa.gov/ttn/oarpg/t1/meta/m32050.html
- ***Emission Inventory Guidance for Implementation of Ozone and Particulate Matter National Ambient Air Quality Standards (NAAQS) AND Regional Haze Regulations****, EPA/OAQPS, EPA-454/R-05-001.Sept/Nov 2005 – pending updates uncertain* http://www.epa.gov/ttn/chief/eidocs/eiguid/index.html
- ***Introduction to Stationary Point Source Emission Inventory Development*****, EIIP Vol. 2, Chapter I,** May 2001
- Main Page of **ClearingHouse of Inventories and Emission Factors (CHIEF)** on EPA web http://www.epa.gov/ttn/chief/eiinformation.html
- **Emissions Inventory Guidance for Anthropogenic Non-Agricultural Ammonia Sources,** Stephen M. Roe, Holly C. Lindquist, Kirstin B. Thesing, Melissa D. Spivey, Randy P. Strait**.** E.H. Pechan & Associates; Roy Huntley, U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, **International Emission Inventory Conference,** Clearwater, FL, June 2004 http://www.epa.gov/ttn/chief/conference/ei13/index.html#ses-1

Reading List (cont'd)

- **NEI Input Format** http://www.epa.gov/ttn/chief/nif/index.html
- **18th Annual International Emission Inventory Conference: "Comprehensive Inventories-Leveraging Technology and Resources"; Papers and Presentations** - Baltimore, Maryland - April 14 - 17, 2009 http://www.epa.gov/ttn/chief/conference/ei18/index.html
- **BENEFITS AND OVERVIEW OF THE ELECTRONIC REPORTING TOOL (ERT);** Paul Baker, MACTEC, & Ron Myers; EPA/OAQPS, RTP, NC, Myers.Ron@epa.gov regards EPA's emission factor data collection system
- **About CROMERR** (The Cross-Media Electronic Reporting Regulation) http://epa.gov/cromerr/about.html

The Colonel Asks - Questions?

Preparation of Fine Particulate Emissions Inventories

Chapter 6 – Nonpoint Sources

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What Will We Discuss in This Lesson

- Basics of Emissions Estimation
- Uncertainty
- Tools to identify nonpoint $PM_{2.5}$ and NH_3 sources and to pick sources to emphasize
- EI Development Options
- Special Considerations for Crustal Matter and Fugitive Dust

Nonpoint inventory includes any stationary source emissions that are not in the point source inventory

Basics of Emissions Estimation

- Emissions data prepared and reported by Source Classification Code (SCC)
  - 10-digit SCC defines a nonpoint emission source
  - EIS Code Table located at: http://www.epa.gov/ttn/chief/eiinformation.html
- Report actual emissions
  - Issue: Permits usually estimate “allowable” or “potential”

Basics of Emissions Estimation (cont'd)

- Calculate emissions using:
  - Activity data
  - Emission factors
  - Control efficiency data
  - Rule effectiveness/rule penetration

Basics of Emissions Estimation (cont'd)

- Emission estimation equation:

$$NPE_A = (EF_A)(Q)\ [(1- (CE)(RE)(RP)]$$

NPE_A	=	Controlled nonpoint source emissions of pollutant A
EF_A	=	Uncontrolled emission factor for pollutant A
Q	=	Category activity
CE	=	% Control efficiency/100
RE	=	% Rule effectiveness/100
RP	=	% Rule penetration/100

Recall from Lesson 2,
some EF's are formulae

Basics of Emissions Estimation (cont'd)

Select Emission Factors (EF)

– www.epa.gov/ttn/chief

CHIEF is Clearinghouse for Emission Inventories & Factors:

- Inventory results and documentation
- SPECIATE & other Inventory Preparation Tools
- Several emissions models
- Emissions modeling/processing information
- Emissions Monitoring Knowledge Base
- AP-42 databases of emission factors, and…

FIRE (contains emission factors to supplement AP-42)

– **http://www.epa.gov/ttn/chief/software/fire/index.html**

– **http://cfpub.epa.gov/oarweb/index.cfm?action=fire.main**

– 22,582 factors in searchable database, current through Sept 2004

– Many "factors" in FIRE are literature cites only; not scrutinized to level of AP-42

More info: info.chief@epa.gov (919) 541-1000)

Basics of Emissions Estimation (cont'd)

- Other sources of Emission Factors
  - State or local emission factors, if more representative than AP-42 or FIRE factors
  - Source testing
  - Emission factor ratios
    - $PM_{2.5}$ emissions calculated from PM_{10} emissions using ratio of $PM_{2.5}$-to-PM_{10} emission factors. See:

      http://www.epa.gov/ttnchie1/software/pmcalc/

Basics of Emissions Estimation (cont'd)

- Obtain activity data (Q) from:
  - Published sources of data
    - National, regional, or state-level activity data often require allocation to counties using county-level surrogate indicator data
  - Survey performed to obtain local estimate of activity
- Activity data may be annual and/or county-level
  - Temporal allocation factors are often used
  - Additional resolution may be needed
    - Large Open Fires, Residential Woodburning

Basics of Emissions Estimation (cont'd)

- Control efficiency (CE)
  - Percentage value representing the amount of a source category's emissions that are controlled by a control device, process change, reformulation, or management practice
  - Typically represented as the weighted average control for an nonpoint source category

Basics of Emissions Estimation (cont'd)

- Rule effectiveness (RE)
  - Adjustment to CE to account for failures and uncertainties that affect the actual performance of the control
- Rule penetration (RP)
  - Percentage of the nonpoint source category that is covered by the applicable regulation or is expected to be complying with the regulation

Typical $PM_{2.5}$ Nonpoint Source Categories

- Fugitive Dust
  (Major source of Crustal Matter)
  - Paved Roads
  - Construction – commercial, residential, roads
  - Agricultural Tilling and Harvesting
  - Unpaved Roads - Public
    - industrial roads should be in point EI
  - Wind Erosion
  - Off-road vehicles
  - Cattle Feedlots (can be in point EI)
  - Mining and Minerals (can be in point EI)
- Lesson 7 will discuss many of these sources

Typical $PM_{2.5}$ Nonpoint Source Categories

- Open Burning

  (Major source of Organic Carbon Matter)

  – Wildland Fires (wild and prescribed)
  – Logging Debris (slash)
  – Land Clearing Debris
  – Agricultural Residue
  – Residential Yard Waste
  – Residential Household Waste
  – Structural Fires
  – Charbroiling

- Lesson 9 will discuss many of these sources

Typical $PM_{2.5}$ Nonpoint Source Categories

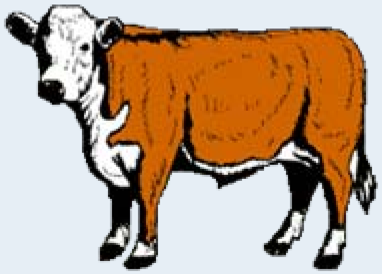
- External Fuel Combustion

  (Major source of Organic Carbon

  also, flyash is a source of Crustal Matter)
  - Residential Woodburning
    - Stoves, Furnaces, Fireplaces
  - Other Residential Fuels
    - Oil and Coal
  - Industrial, Commercial Institutional Boilers
    - Those too small to include in point sources
    - Overlap with point source inventory
- Lesson 9 will discuss Residential Woodburning

Typical NH_3 Nonpoint Source Categories

- Agricultural Ammonia
  - Animal Waste
    - Should be in point source EI where possible
    - Cows, Hogs, Chickens, other livestock
  - Fertilizer Application
    - Agricultural, but also residential / commercial



- Other Sources of Ammonia
  - Wildland Fires
  - Fertilizer Manufacturing / Wastewater Treatment
    - Should be in point source EI
  - Miscellaneous Lesser Sources
    - Human perspiration
    - Wild / domestic animal waste
- Lesson 8 discusses Ammonia Sources

Tools to Identify Important Nonpoint Sources of $PM_{2.5}$ or NH_3 Emissions

Existing Inventories – A Good "Starting Point" to Identify Key $PM_{2.5}$ & Ammonia Sources

- Toxics Release Inventory (TRI)
  - http://www.epa.gov/TRI/tridata/index.htm
- State/Local/Tribal EIs
- National Emission Inventory (NEI)
  - Now includes HAPs
  - 2002 "Booklet", Data, Documentation
    - http://www.epa.gov/ttn/chief/net/2002neibooklet.pdf
    - http://www.epa.gov/ttn/chief/net/2002inventory.html#inventorydata
    - http://www.epa.gov/ttn/chief/net/2002inventory.html
  - 2005 NEI Data, Documentation
    - http://www.epa.gov/ttn/chief/net/2005inventory.html#inventorydata
    - http://www.epa.gov/ttn/chief/net/2005inventory.html

Tools to Identify Important Nonpoint Sources of $PM_{2.5}$ or NH_3 Emissions? (cont'd)

- **EIIP Area Source Guidance (Volume III) for Sources of PM Emissions**
  - Chapter 2: Residential Wood Combustion, Revised Final, Jan. 2001
  - Chapter 16: Open Burning, Revised Final, Jan. 2001
  - Chapter 18: Structure Fires, Revised Final, Jan. 2001
  - Chapter 24: Conducting Surveys for Area Source Categories, Dec. 2000

Tools to Identify Important Nonpoint Sources of $PM_{2.5}$ or NH_3 Emissions? (cont'd)

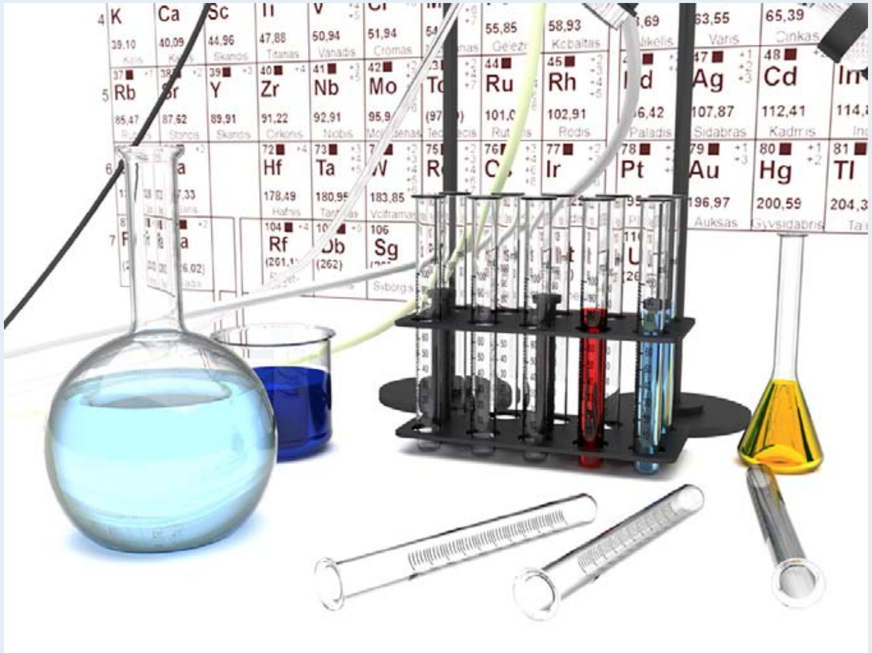
- Nonpoint Category Method Abstracts for Sources of PM Emissions
  - Charbroiling, Dec. 2000
  - Vehicle Fires, May 2000
  - Residential and Commercial/Institutional Coal Combustion, April 1999
  - Fuel Oil and Kerosene Combustion, April 1999
  - Natural Gas and Liquefied Petroleum Gas (LPG) Combustion, July 1999
- Link for EIIP and Area Source Abstracts
  - http://www.epa.gov/ttn/chief/eiip/

Tools to Identify Important Nonpoint Sources of $PM_{2.5}$ or NH_3 Emissions? (cont'd)

Receptor Models

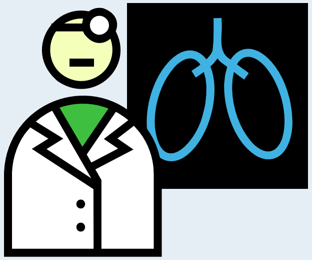
- ~ reconciling source and ambient chemical characteristics
- ~ daily & time-series

- Tool to Identify Source Types
  - Fossil vs. Contemporary Carbon
  - Gas vs. diesel carbon
  - Cold starts, smokers
- Tools
  - Chemical Mass Balance (CMB)
  - Chemometric Multivariate Methods
- Usefulness
  - Refine EI, bound certainty



Triage Approach to Identify Key Source Categories to Emphasize

- Consider each NEI category - Is it Important?
  - Will it make a difference?
  - Potential impact on AQ, considering e.g., emissions, speciated ambient measurements, receptor modeling
  - Give *some weight* to emission reductions potential
  - Are any important categories missing from the NEI or previous S/L/T inventories?
  - What is *feasible* in your time frame?
  - Can you “make a difference”?



- *Focus* on important, “difference-making” categories

Uncertainty in the EI

- Usually less accurate/precise than desired
- Quantitative estimate of the EI uncertainty is difficult.
- Ambient data comparisons can help.
- Receptor models can help indentify and quantify (or at least “bound”) uncertainties
- Some new grid modeling procedures being tested can be helpful
  - compare speciated model estimates with speciated ambient data for the same time periods

EI Development Options

- Approaches Available to State, Local, and Tribal (S/L/T) Agencies:
  - S/L/T Agency develops its own inventory following EIIP (or more recent) procedures
  - Combination of S/L/T data and NEI Defaults
    - Substitution of S/L/T data to replace NEI
    - Category –by- category decision
    - Where S/L/T data are available / better
  - Use NEI default estimates

Summary ~ EI Development and Tools

- Nonpoint EI's are challenging and uncertainty is often higher than desired
- Prioritizing effort is important
- Many tools are available
- Many opportunities to use local information

Questions?

LizMarie 2005

Special Considerations for Airborne Crustal Matter Emissions

Peter Baker 2006

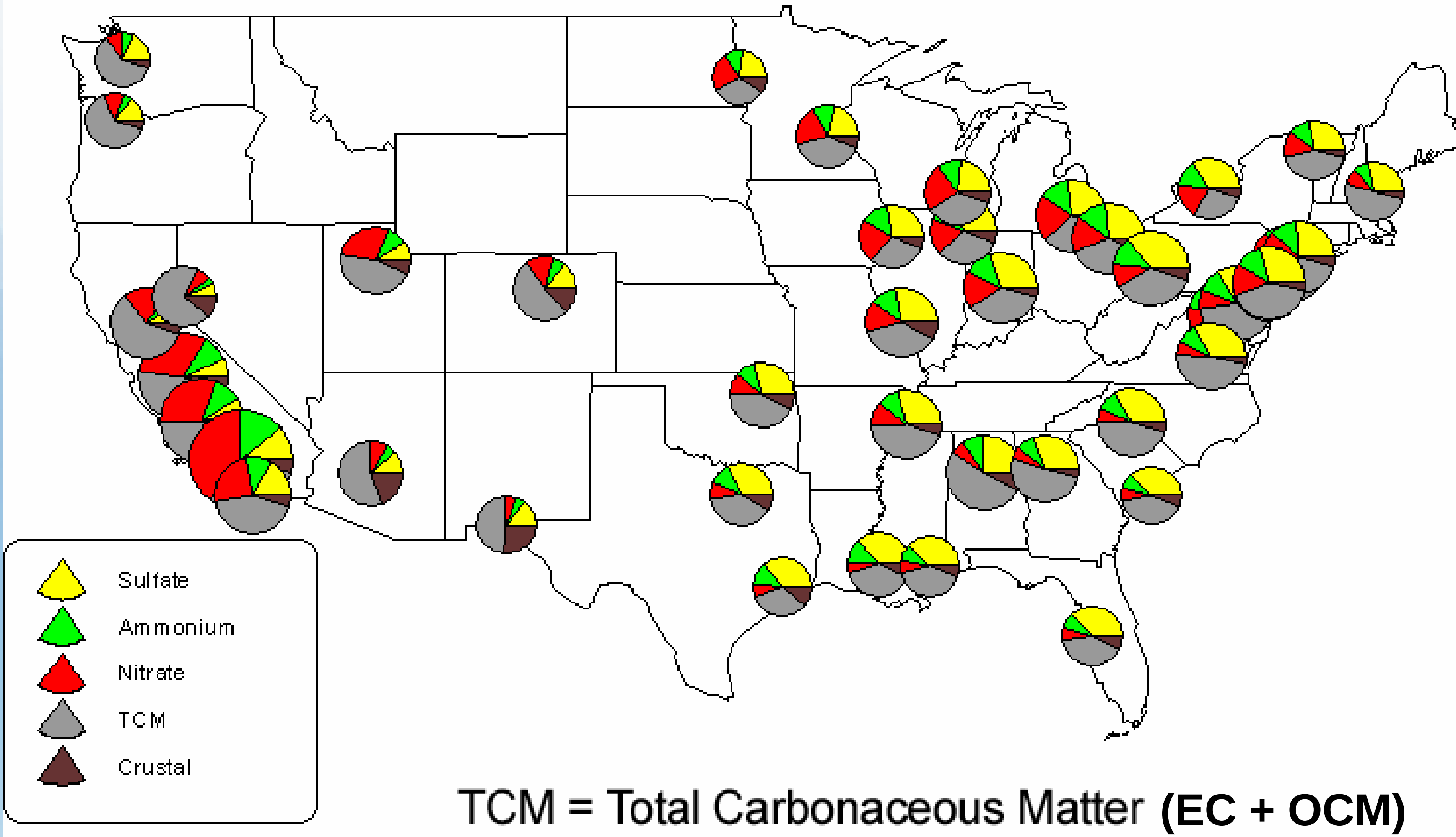
Fugitive Dust Emissions

- Fugitive dust is the principal source of crustal materials in the ambient air
- Categories emitting fugitive dust:
  - Unpaved & paved roads
  - Agricultural tilling
  - Construction (residential, commercial, roads)
  - Windblown dust
  - Industrial mining and minerals operations
  - Sandblasting
- Other sources of crustal materials
  - Fly ash

Key Issues for Discussion

- Fugitive Dust emissions are very high in the EI
  - Composed mainly of crustal material (earth oxides)
- Crustal matter is not a major component of ambient samples of PM2.5
  - a few exceptions, mainly in Southwestern US
- Ambient data vs. EI ~ apparent inconsistency
  - Largely explained by capture of dust emissions near source by surface features
  - Still some lingering issues

EPA STN Annual Averages of Urban PM2.5 Components (Sep 2001-Aug 2002)



TCM = Total Carbonaceous Matter **(EC + OCM)**

2005 Fugitive Dust $PM_{2.5}$ Emissions in OHIO

	Ag Crop Tilling	Unpaved Roads	Paved Roads	Const.
Ohio	22,448	10,086	5,978	7,809
US Total	535,993	840,556	122,436	199,255

Interaction of Surface Cover (Vegetation & Structures) with Fugitive Dust

- Dust is usually emitted at ground level
  - Small vertical component (except wind storms)
  - Ample “opportunity” for interaction w/ surroundings
- Surface cover *does* capture dust
  - Windbreaks – a “staple” in control of wind erosion
    - Traditionally to slow wind on downwind side
    - Also acts to “trap” or “filter” particles
      - Raupach’s work on entrapment effects
      - Dust transmittance through a windbreak is close to the optical transmittance
  - Stilling Zone – Lower 3/4 of canopy

Interaction of Surface Cover (Vegetation & Structures) with Fugitive Dust (cont'd)

- Two new terms were coined to describe the interaction of particles with surface cover Capture Fraction (CF)
    - Portion of Fugitive Dust Emissions (FD) removed by nearby surface cover
  - Transport Fraction (TF)
    - Portion that is transported from the source area

$$\boxed{CF + TF = 1}$$

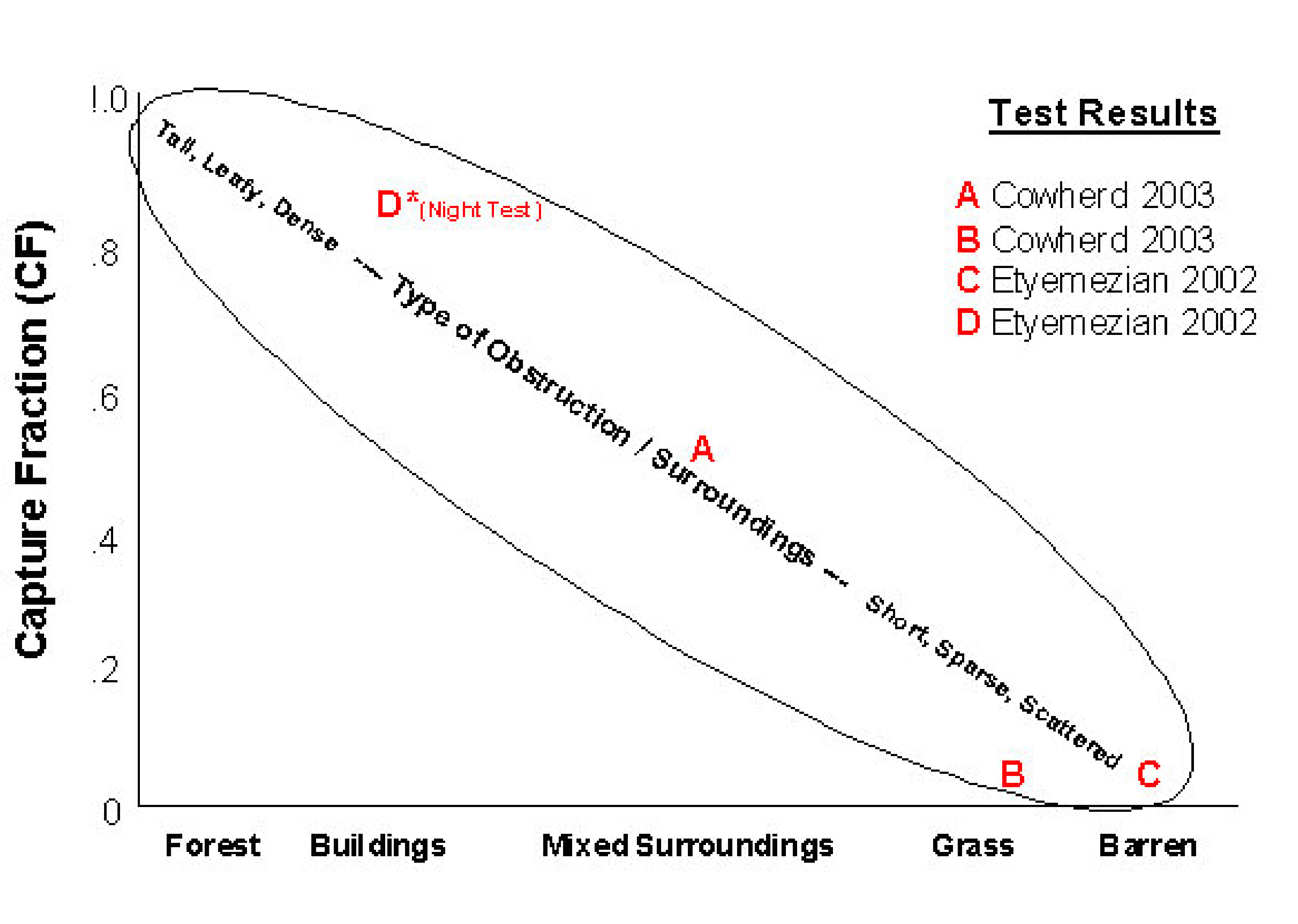
See Pace 2005
http://www.epa.gov/ttn/chief/emch/dustfractions/transportable_fraction_080305_rev.pdf

Which Area Will Have the Higher CF?

Micky 2006

Mister-E 2006

Capture Fraction ~ Conceptual Model and Field Measurement Results



Estimates of CF for Specific Surface Conditions

Surface Cover Type	CF (Est)
Smooth, Barren or Water	0.0 – 0.1
Agricultural	0.1 - 0.4
Grasses	0.1 - 0.4
Scrub and Sparsely Wooded	0.1 - 0.4
Urban	0.25 - 0.75
Forested	0.8 - 1.0

Fugitive Dust Modeling Issues

- Gaussian Models
  - Many CF removal mechanisms can be accounted for within the models
    - rarely utilized - requires empirical coefficients
    - limited data & guidance
- Grid Models
  - Remix particles w/in lowest layer at each time step (underestimates removal by gravitational settling)
  - Ignore removal processes in initial grid
    - Very significant omission (unless grid is VERY small)
  - CF applied to EI when input to grid models
  - CF should be based on 1km vegetative coverages & land use when available

Notes on Use of the TF in Emissions Inventory & Modeling Applications

- Do NOT use TF to reduce the emissions inventory
- Do NOT use TF with Gaussian Models
  - Instead, use features of these model properly
- Use TF with Grid Models (with proper caveats)
  - There ARE other issues with the inventory – the TF concept should NOT be expected to fully account for overestimation of crustal fraction of ambient measurements
- TF concept is evolving
  - Grid Model modifications could (over time) eliminate need for TF concept

Crustal Materials ~ Conclusions

- Crustal Materials
  - relatively small part of $PM_{2.5}$ in the ambient air
  - mainly released near the ground
  - surface features often capture the dust near its source
- Capture / Transport Fraction…
  - provides a useful way to account for near source removal (when used with Grid Models)
  - many opportunities to improve model performance thru research
  - There is much work to do to refine the concept

Questions?

Preparation of Fine Particulate Emissions Inventories

Chapter 7 – Fugitive Dust Area Sources

PECHAN
E.H. Pechan & Associates, Inc.

Fugitive Dust Emissions - Overview

- This session will…
  - Provide overview/review of terms
  - Introduce/overview four categories of FD emissions
    - Agricultural Tilling
    - Paved Roads
    - Unpaved Roads
    - Construction

Fugitive Dust

- **Fugitive Dust** – Particulate matter generated/emitted from various open air operations, which do not pass through a stack or vent and generally are addressing large land areas
- **Fugitive Process Emissions** – generated by either open or enclosed industrial operations but escape hooding or a stack; may be emitted through a vent, windows, etc.
- **See:** WRAP Fugitive Dust Handbook for guidance – especially in Western climates and areas http://www.wrapair.org/forums/dejf/fdh/index.html
- **Details of the NEI Methods** may be found at: http://www.epa.gov/ttn/chief/net/2002inventory.html#documentation

Other FD Categories not Discussed Here

- Windblown dust
- Sandblasting
- Demolition / debris removal
- Power blowing: leaves, edging, grass clippings

2005 Fugitive Dust $PM_{2.5}$ Emissions in OHIO

	Ag Crop Tilling	Unpaved Roads	Paved Roads	Const
Ohio	22,448	10,086	5,978	7,809
US Total	535,993	840,556	122,436	199,255

Agricultural Tilling - What We Will Cover

- NEI Method
- Ways to Improve upon NEI
- Example Calc form CARB

Agricultural Tilling - NEI Method

- Emission Calculation

$$E = c * k * s^{0.6} * p * a$$

where: E = PM emissions, lbs per year

c = constant 4.8 lbs/acre-pass

k = dimensionless particle size multiplier (PM_{10}= 0.21; $PM_{2.5}$ = 0.042)

s = silt content of surface soil, defined as the mass fraction of particles smaller than 75 µm diameter found in soil to a depth of 10 cm (%)

p = number of passes or tillings in a year

a = acres of land tilled

Agricultural Tilling - NEI Method (cont'd)

- Activity Data (acres of land tilled)
  - 1998 County-Level Activity Data
    - Acres of crops tilled in each county by crop type and by tilling method obtained from CTIC
    - Five tilling methods include:
      - no till
      - mulch till
      - ridge till
      - 0 to 15 percent residue
      - 15 to 30 percent residue

Agricultural Tilling - NEI Method (cont'd)

- Emission Factor (lbs TSP per acre tilled)
  - Emission factor comprises:
    - Constant of 4.8 lbs/acre pass
    - Silt content of the surface soil
    - Number of tillings per year (conservation and conventional use)
    - Particle size multiplier for PM_{10} and $PM_{2.5}$

Agricultural Tilling - NEI Method (cont'd)

- Emission Factor (cont'd) - Silt content

Soil Type	Silt Content (%)
Silt Loam	52
Sandy Loam	33
Sand	12
Loamy Sand	12
Clay	29
Clay Loam	29
Organic Material	10-82
Loam	40

  – Soil types assigned to counties by comparing USDA surface soil and county maps

Agricultural Tilling - NEI Method (cont'd)

- Emission Factor -- Number of Tillings

Crop	Conservation Use	Conventional Use
Corn	2	6
Spring Wheat	1	4
Rice	5	5
Fall-Seeded Small Grain	3	5
Soybeans	1	6
Cotton	5	8
Sorghum	1	6
Forage	3	3
Permanent Pasture	1	1
Other Crops	3	3
Fallow	1	1

Agricultural Tilling - NEI Method (cont'd)

- Emission equation used for years prior to 1999
- For 1999/2002, number of acres tilled for each of the five tillage types was estimated based on linear interpolation of national-level data available for 1998 and 1999/2002
- Developed national growth factors by tillage type for 1999/2002, using 1998 as basis
- Growth factors applied to county level emissions for 1998 to estimate county level emissions for 1999/2002
- Assumed no controls

Agricultural Tilling - Improving Upon the NEI

- Use crop-specific acreage and tilling practice data from state/local agencies
- Use state/local emission factors
- Perform field study to determine local silt content percentage of surface soil http://www.epa.gov/ttn/chief/ap42/appendix/app-c2.pdf
- Crop Calendars: Use state/local data to determine time and frequency of e.g., land prep., planting, and tilling

Example Crop Calendar for Corn

Farming Operations	Crop Cycles Per Year	Passes Per Crop Cycle	Fraction of Acreage Per Cycle	Passes During Month											
				Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Land Preparation															
Stubble Disc	1	1	1.0												
Finish Disc	1	1	1.0												
List & Fertilize	1	1	1.0												
Mulch Beds	1	1	1.0												
Planting	1	1	1.0												
Cultivation	1	2	1.0												
Harvesting	1	1	1.0												

(Reference: Gaffney & Yu)

California Air Resources Board (CARB) Study

- Reference
  - *Computing Agricultural PM_{10} Fugitive Dust Emissions Using Process Specific Emission Rates and GIS,* Patrick Gaffney and Hong Yu, CARB
  - Presented at 12^{th} International Emission Inventory Conference, San Diego, CA, April 29 May 1, 2003
  - Paper and slides available in PDF files: http://www.epa.gov/ttn/chief/conference/ei12/index.html

CARB Study (cont'd)

- Statewide PM_{10} EI for:
  - Land preparation activities
  - Harvest activities
- Goals:
  - Obtain current, crop-specific acreage data
  - Develop crop-specific temporal profiles (crop calendars)
  - Develop emission factors for all crops

CARB Study (cont'd)

- Crop-specific Acreage Data
  - County-level data from CA Dept. of Food and Agriculture
  - Data generated annually by crop and by county
  - Includes over 200 crops and 30 million acres

CARB Study (cont'd)

- Crop Calendars
  - Developed for 20 most important crop types
    - Importance based on acreage and potential emissions
  - Define temporal periods of farming operation activities by crop type

CARB Study (cont'd)

- Emission Factors (EFs)
  - Previous EIs:
    - Land Preparation: AP-42 Tilling factor (4.0 (lbs PM_{10}/acre-pass) applied to all operations
    - Harvesting: Estimated for only 3 crop types for which EFs were available
  - Improvements:
    - Conducted field testing to develop EFs for more operations
    - Crop & operation specific (for crop calendars)

CARB Study (cont'd)

Land Preparation Emission Factors

	(lbs PM_{10}/acre-pass)
Root Cutting	0.3
Discing, Tilling, Chiseling	1.2
Ripping, Subsoiling	4.6
Land Planning & Floating	12.5
Weeding	0.8

EFs used as surrogates for other land preparation operations

CARB Study (cont'd)

Harvest Emission Factors

	(lbs PM_{10}/acre-pass)
Cotton Harvest	3.4
Almond Harvest	40.8
Wheat Harvest	5

Assigned to over 200 crop types and adjusted using a "division factor" based on consultation with agricultural industry

Questions?

PAVED ROADS – Overview

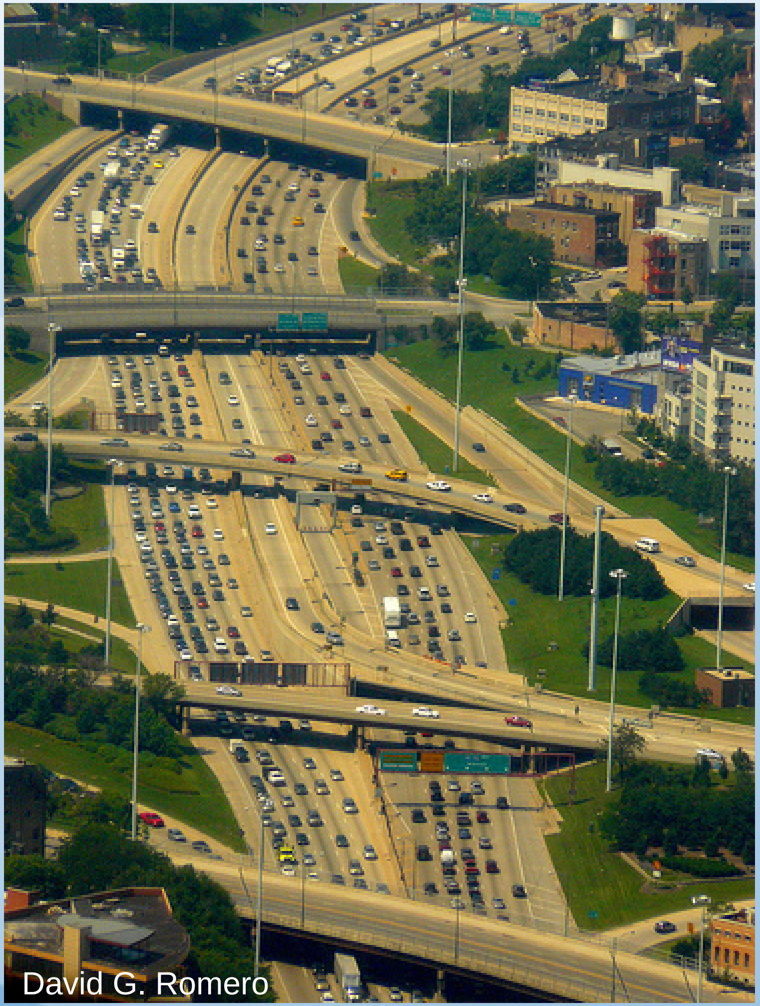
- SCC: 2294000000
- Pollutants: PM_{10}, $PM_{2.5}$

NEI Method

Controls & Precipitation

How to improve upon NEI

Emerging technologies



PAVED ROADS - NEI Method (cont'd)

- Emission Calculation

$$EM_{s,t,m} = VMT_{s,t,m} * EF_{s,t,m} (1 - * CE * RP * PMF)$$

where:	EM	=	PM_{10} emissions, tons per month
	VMT	=	VMT, miles per month (by road type)
	EF	=	tons per mile (by road type)
	CE	=	control efficiency
	RP	=	rule penetration
	PMF	=	precipitation mitigation factor
	$PM_{2.5}$	=	PM_{10} emissions x 0.25
	m	=	month
	s	=	state
	t	=	road type class (12 classes)

PAVED ROADS - NEI Method (cont'd)

- Emission Factor
  - Empirical emission factor equation from AP- 42

$$EF = C_S * (sL/2)^{0.65} * (Wt/3)^{1.5} - CF_V$$

where:

EF	=	paved road dust emission factor for all vehicle classes combined (grams per mile)
C_S	=	size constant
sL	=	road surface silt loading (g/m^2)
Wt	=	average weight of all vehicle types combined (tons)
CF_V	=	Correction factor for c1980 vehicle fleet exhaust, brake wear, and tire wear

PAVED ROADS - NEI Method (cont'd)

- Emission Factor (cont'd)
  - Paved road silt loadings assigned to each of the twelve functional roadway classifications
    - Road types with average daily traffic volume (ADTV) < 5,000 vehicles per day = 0.20 g/m^2
    - Freeways = 0.015 g/m^2
  - See AP-42, Section 13.2.1 for more information
  - AP-42 emission factors for paved roads only apply to reentrained dust
  - Use MOBILE model for estimating PM from tailpipe exhaust, brake wear, and tire wear

PAVED ROADS - NEI Method (cont'd)

- Controls
  - Control efficiency (CE) of 79 percent applied to:
    - Urban and rural roads in serious PM NAAs; and
    - Urban roads in moderate PM NAAs
      - Corresponds to vacuum sweeping on paved roads twice per month
  - Rule penetration (RP) varies by road type and NAA classification (serious or moderate)

PAVED ROADS - NEI Method (cont'd)

- Monthly Precipitation Adjustment
  - Emission factor multiplied by a rain correction factor, calculated as follows:

$$(365 - p * 12 * 0.5) / 365$$

where: p = the number of days in a given month with greater than 0.01 inches of precipitation (from stations representative of urban areas)

PAVED ROADS
Improvements to NEI Method

- Evaluate Silt Loading (sL)
  - Are AP-42 defaults reasonable?
  - Local sampling
    - Method described in AP-42 13.2.1.2
    - Only consider if you can collect enough samples to give a good representation
  - TRAKER
    - Mobile “road plume” sampling device
    - Treasure Valley – AP-42 silt values too low
      - » by a factor of 1.5 for summer conditions
      - » by a factor of 3.8 for winter

Questions?

TPace '09

UNPAVED ROADS - What We Will Cover

- NEI method
- How to improve upon NEI

UNPAVED ROADS - NEI Method

- Overview
  - Activity used to calculate emissions (VMT on unpaved roads) based on roadway mileage and average traffic volumes
  - Emission factor adjusted for precipitation effects
  - Emissions calculated at state level by roadway class
  - Allocated from state/roadway to county/roadway

UNPAVED ROADS - NEI Method

$$\mathit{Unpaved\ VMT}_{Roadtype} = \mathit{Mileage}_{Roadtype} * \mathit{ADTV} * \mathit{DPY}$$

where:

Unpaved VMT	=	road type specific unpaved VMT (miles/year)
Mileage	=	total number of miles of unpaved roads by functional class (miles)
ADTV	=	average daily traffic volume (vehicle/day)
DPY	=	number of days / year road open

UNPAVED ROADS - NEI Method (cont'd)

- Activity
  - Roadway mileage on unpaved roadways by functional class and State from Federal Highway Administration Highway Statistics (Table HM-51), updated annually
  - Unpaved road mileage allocated to average daily traffic volume (ADTV) categories based on distribution in Highway Statistics Table HM-67 (table not published after 1996)
  - Unpaved road VMT temporally allocated by month using NAPAP temporal allocation factors for total VMT

UNPAVED ROADS - NEI Method (cont'd)

- Emission Factor
  - AP-42 emission factor equation

$$EF = [k * (s/12) * (S/30)^{0.5}]/[(M/0.5)^{0.2}] - C$$

where:

EF	=	size specific emission factor (pounds per VMT)
k	=	empirical constant (1.8 lb/VMT for PM_{10}-PRI, 0.27 for $PM_{2.5}$-PRI)
s	=	surface material silt content (%)
M	=	surface material moisture content (%)
S	=	mean vehicle speed (mph)
C	=	emission factor for 1980's vehicle fleet exhaust, brake wear, and tire wear (0.00047 lb/VMT for PM_{10} and 0.00036 lb/VMT for $PM_{2.5}$)

UNPAVED ROADS - NEI Method (cont'd)

- NEI Default Emission Factor Input Values
  - Surface material silt content(s)
    - Average state-level values developed/available at ftp://ftp.epa.gov/EmisInventory/finalnei99ver2/criteria/documentation/xtra_sources/
  - Mean vehicle weight (W)
    - National average value of 2.2 tons (based on typical vehicle mix)
  - Surface material moisture content (M_{dry})
    - 1 percent

UNPAVED ROADS - NEI Method (cont'd)

- Adjustments for precipitation
  - Emission factor multiplied by a precipitation correction factor, calculated as follows:

$$(365 - p) / 365$$

where: p = the number of days in a given month with at least 0.01 inches of precipitation

  - Precipitation data from one meteorological station in state used to represent all rural areas of the state
  - Local climatological data available from National Climatic Data Center at http://www.ncdc.noaa.gov/oa/ncdc.html

UNPAVED ROADS - NEI Method (cont'd)

- Allocation of State emissions to county level
  - Unpaved road emissions are allocated from the State/roadway type level to the county/roadway type level based on the ratio of the rural population in a given county to the rural population of the state

UNPAVED ROADS - NEI Method (cont'd)

- Controls - NEI Defaults
  - Urban unpaved roads in moderate PM NAAs:
    - 96% control efficiency, 50% rule penetration
    - Simulates paving of the unpaved roads
  - Rural unpaved roads in serious PM NAAs:
    - 75% control efficiency, 50% rule penetration
    - Simulates chemical stabilization
  - Urban unpaved roads in serious PM NAAs:
    - 90% control efficiency, 75% rule penetration
    - Simulates combination of paving and chemical stabilization

UNPAVED ROADS - Improvements to NEI

- Review NEI defaults for representativeness
- Use local data when possible for activity and emission factor inputs
- Focus on collecting data for local unpaved VMT estimates
  - NEI unpaved VMT data is based on outdated data for estimating ADTV on unpaved roads
  - Local information on ADTVs of unpaved roads should be used to estimate unpaved VMT, where possible

Other Resources

- "Crustal Matter: Exploring the Differences between Ambient Air Samples and Emissions Inventory," J. James, C. Clark and J. Rice, North Carolina State University http://www.epa.gov/ttn/chief/conference/ei18/session4/james.pdf
- **WRAP Fugitive Dust Handbook, 2004,** Richard Countess, Countess Environmental, Westlake Village, CA (last revised May, 2007 with unpaved roads calculator) http://www.wrapair.org/forums/dejf/fdh/ch6-unpavedroads.html

Questions?

Foltzwerk 2007
ALASKANENT 2009

CONSTRUCTION – Overview

SCCs:

Residential - 2311010000

Commercial - 2311020000

Road – 2311030000

Filterable - all

1999 $PM_{2.5}$ NEI

Res - 5%

Comm - 40%

Road - 55%

State Attention-

Invited but not likely to be high priority

CONSTRUCTION
NEI Method

*EM = EF * AD * d * Silt CF * Moisture CF * CE*

- EF: Emission Factor in Ton/AD/Mo
- AD: Acres disturbed (AD) per month
- d: Duration of project in months - from open to landscaped
- Silt CF: Silt Content Correction Factor
- Moisture CF: Soil Moisture CF
- CE: Control Efficiency

Note: Similar Methods for Each of 3 Categories

CONSTRUCTION NEI Correction Parameters

- Soil Moisture Level Correction Factor (Moisture CF)

  Moisture Level Corrected Emissions = Base Emissions x (24/PE)

  where: PE = Precipitation-Evaporation value for county

  - PE values from Thornthwaite's PE Index

    http://proceedings.esri.com/library/userconf/proc01/professional/papers/pap466/p466.htm

- Silt Content Correction Factor (Silt CF)

  Silt Content Corrected Emissions = Base Emissions x (s/9%),

  where: s = % dry silt content in soil for area being inventoried

  County-specific dry silt values are applied to PM_{10} emissions for each county

Note: These corrections apply to all 3 Construction categories

CONSTRUCTION
Sources of Acres Disturbed (AD) Data

AD = Surrogate * Surrogate-to-acres factor

- **Surrogates:**
  - **Residential** – Total housing start data - available for monthly housing unit starts grouped by 1-unit, 2-unit, 3-4 units, and 5+ units – normally compiled by local/county building permit offices
  - **Commercial** – Dollar amount (1.6 acres per $Million of reported estimated construction by county
  - **Highway –** Dollar amount compiled by FHWA by state and county, by category
- **Default factors:**
  - Surrogate-to-acres defaults for each construction type
  - Note: NEI uses national data sources (DOC, DOL, FHWA) and allocates to county – **Local data WILL improve these surrogate factors**

CONSTRUCTION NEI Method

Control Efficiencies (CE) - NEI default

- Apply a control efficiency of 50 percent for both PM_{10} and $PM_{2.5}$ emissions for PM_{10} NAAs; all other areas 0 percent
- Control efficiency represents Best Available Control Method (BACM) controls on fugitive dust construction activities for these counties

RESIDENTIAL CONSTRUCTION
NEI Emission Calculations

- 1-Unit Structures without Basements, All 2 Unit Structures, and Apartments
- *Emissions = (0.032 tons* PM_{10}*/acre/month) x B x f x d),* where:

  B = no. of housing starts without basements

  F = buildings-to-acres conversion factor

  D = duration of construction in months

Note: Volume of soil removed in basement dwellings is estimated & emissions are estimated as *0.012 tons* PM_{10} */1000 yards3 of cut/fill*

COMMERCIAL & ROAD CONSTRUCTION NEI Emission Calculation Specifics

COMMERCIAL CONSTRUCTION NEI Emission Calculations

Formula for calculating emissions:

Emissions = (0.19 *tons/acre/month) x $ x f x d*

where: $ = dollars spent on nonresidential construction in <u>millions</u>

f = dollars-to-acres factor

d = duration of construction activity in months (default -11 mo.)

Get local construction acres directly, if possible (do not rely on state dollar-to-acre conversions or general duration data)

COMMERCIAL CONSTRUCTION NEI Emissions Calculations (cont'd)

- Allocation of National Data to Counties
  - National level activity allocated to counties using data from **Quarterly Census of Employment and Wages,** Bureau of Labor Statistics, http://www.bls.gov/cew/
  - Applied Dun & Bradstreet county proportion of the state total to the BLS state total to estimate employment for counties where data were withheld, *www.dnb.com*

ROAD CONSTRUCTION
NEI Emission Calculations (cont'd)

The formula for calculating emissions is:

$$\textit{Emissions} = (0.42 \textit{ tons } PM_{10}/\textit{acre/month}) \times \$ \times f1 \times f2 \times d$$

where:	$	=	state expenditures for capital outlay on road construction
	f1	=	$-to-miles factor
	f2	=	miles-to-acres factor
	d	=	duration of roadway construction activity in months (assumed 12 months)

ROAD CONSTRUCTION
NEI Emission Calculations (cont'd)

- Obtain state expenditure data for capital outlay for six classifications
  - Interstate, urban
  - Interstate, rural
  - Other arterial, urban
  - Other arterial, rural
  - Collectors, urban
  - Collectors, rural
- Estimate miles of new road constructed
  - $4 million/mile for interstate roads
  - $1.9 million/mile for other arterial and collector roads (NCDOT)

ROAD CONSTRUCTION NEI Emissions Calculations (cont'd)

- Estimate acres for each road type using estimates of acres disturbed per mile (f2):
  - Interstate, urban and rural; Other arterial, urban - 15.2 acres/mile
  - Other arterial, rural - 12.7 acres/mile
  - Collectors, urban - 9.8 acres/mile
  - Collectors, rural - 7.9 acres/mile

(Reference: ***Estimating Particulate Matter Emissions from Construction Operations*****,** prepared by Midwest Research Institute for U.S. Environmental Protection Agency, 1999.)

CONSTRUCTION
Improvements to NEI

- Obtain information on private road construction activity

  (Possible source: Construction Industry Association)
- Obtain local information on soil moisture content, silt content, and control efficiency
- Get local construction acres directly, if possible (do not rely on state $-to-acre and $-to-miles conversions or general duration data)
- Get local information on start dates, duration and local practices for dust mitigation

Questions?

Preparation of Fine Particulate Emissions Inventories

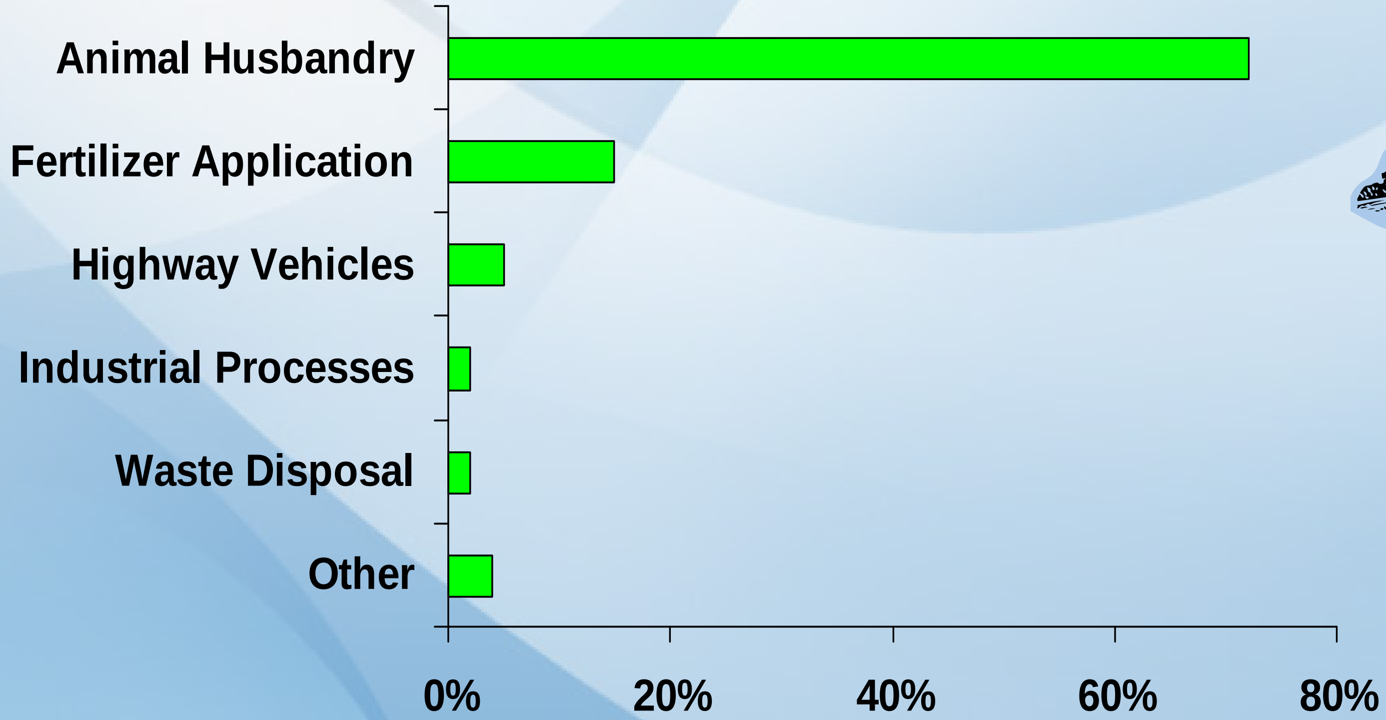
Chapter 8 – Ammonia Emissions from Animal Husbandry

PECHAN
E.H. Pechan & Associates, Inc.

What should you take from this session?

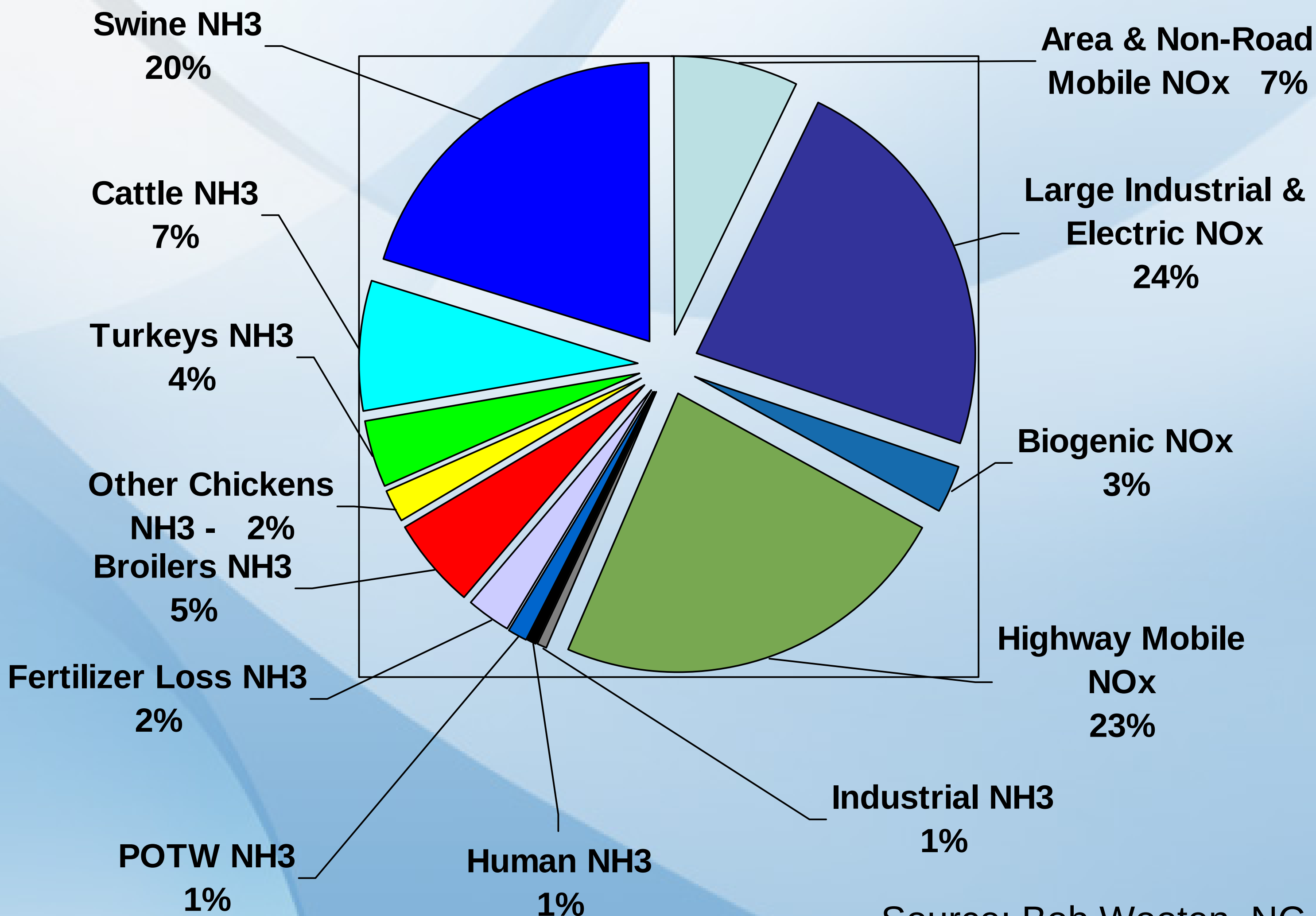
- A better understanding of factors that relate to ammonia from animal operations and why they are important, or unimportant, to you
- Data sources and differences in presentation
- How are/were emission factors determined
- Models and procedures available to estimate emissions
- Variances by state, animal types, and husbandry practices

NH_3 – Precursor to Ammonium Sulfate & Nitrate (National Emissions ~ 4.8 M TPY)



Example – Nitrogen Emissions in North Carolina

Percentages of Nitrogen from NO_x and Ammonia Sources (as N)



Source: Bob Wooten, NC DAQ

NH_3 – Potential Issues w/Existing EI?

- Inventories of NH_3 are “new” to the industrial point source community, the air agencies and the testing community – thus not yet confirmed that many emission sources are well characterized/quantified
- Some confusion on how to report – as NH_3,NH_4 ion, N, or mass of whole compound(s) such as ammonium sulfate (almost 10X) – Use NIF codes/definitions
- Continuing studies
- Just be alert and probing

The Agricultural/Related Sources Are:

- **Animal Operations**
  - Poultry
  - Cattle
  - Hogs/swine
  - **Fertilizer Application**
- **Other (not agricultural)**
  - Pets
  - Wild animals
  - Human (generally, waste treatment plant as point)
  - Plants (anaerobic decomposition, primarily)

State to State Variability

- Many states have many farm animals of various types (e.g., California & Texas) and lots of experience quantifying emissions
- Others have few or limited variety
- Most states are "focused" on production of a few types of animals (e.g., NC & Iowa - swine)
- Some states have relatively few animal operations and thus emissions (e.g., AK & ID) but can still be locally important

A North Carolina Hog Farm w/Lagoon

EPA Mandate (by NAS study) to Update NH_3 Emissions from Animal Husbandry

- Ammonia emission factors continue to be lacking in quality and detail – lots of variability and few valid parametric test results applicable to real conditions
- Make improvements:
  - Revise/refine emission factor selections and tests
  - Reflect EPA "2-year" studies underway (2007) http://www.epa.gov/oecaagct/airmonitoringstudy.html
  - Refine information on variability of emissions due to various manure handling practices
  - Properly use information from National Agricultural Statistics Service (NASS) on animal populations, by average live weight

Testing/Measuring NH_3 for Factors

- General field methods
  - Chamber method for lagoons, etc.
  - Up-wind/down-wind ambient & reverse model; generally FTIR
  - Other “over-water” flux measurements
- Variables of importance
  - Temp, pH, wind, fan speed/volumes, water and wind currents, non uniform flow patterns, etc. etc.
  - Parametric testing becomes quite difficult as well as making proper analysis of results

Continued Work on Ammonia from Animal Husbandry is Needed

- Continue to test and develop better methods
- Continue to incorporate data/info. from **Effluent Guidelines** project
  http://www.epa.gov/agriculture/anafoidx.html
  http://www.epa.gov/npdes/regulations/cafo_final_rule_preamble2008.pdf
- Continue review & progress on meeting NAS recommendations (previous slide)
  http://books.nap.edu/catalog.php?record_id=10391#toc
- **Continue QA** improvements

Basis for Interim NEI Improvements

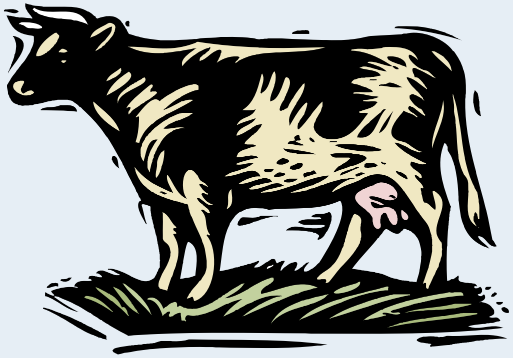
- Provide improved populations, practices, and emissions data
- Switch to a common process-based framework, that is transparent and allows updating periodically
- Motivate relevant data updates and provide a database to store them
- Educate users about data limitations and uses
- Higher animal production states have begun to offer improvements and new methods

Current NEI Estimation Methodology Overview

- **Step 1**: Estimate average annual animal populations by animal group, state, and county
- **Step 2**: Identify Manure Management Trains (MMT) used by each animal group and then estimate animal populations using each MMT
- **Step 3**: Estimate nitrogen emissions using each type of MMT and general manure characteristics

Current Estimation Methodology – Overview (cont'd)

- **Step 4**: Determine best emission factors for each component/MMT
- **Step 5**: Estimate ammonia emissions for each animal group by MMT/county
- **Step 6**: Estimate future ammonia emissions for years 2011, 2014, 2017, 2020, and 2030 (may change in final guidance)



Step 1: Population Estimates

- Animals: dairy, beef, swine, and poultry
  - Keep age/weight groups & animal types distinct
- State-level population: latest NASS
- County apportionment: using latest Census of Agriculture
  - Privacy Issue - Where state and/or county is not disclosed, divide equally

Animal Population Data - USDA

- Animal populations by state & county
- Every 5 years, ending in 2 or 7
- 2007 is most recent
  http://www.agcensus.usda.gov/Publications/2007/index.asp

USDA Census of Agriculture - Hints

Read carefully - Terminology can be confusing

Cows, Cattle, Calves, Heifers, Beef cows, Milk (milch) cows, Steers, Steer calves, Bulls, Bull calves, Heifer calves, Chickens, Layers, Broilers, Pullets, etc.

- Ask your state agricultural statisticians to explain the nuances and differences, if uncertain
- Census lists county level data but sometimes not due to confidentiality issues
- State records may have more information such as – permits
- Producer associations often have data they have compiled from members that they MAY share

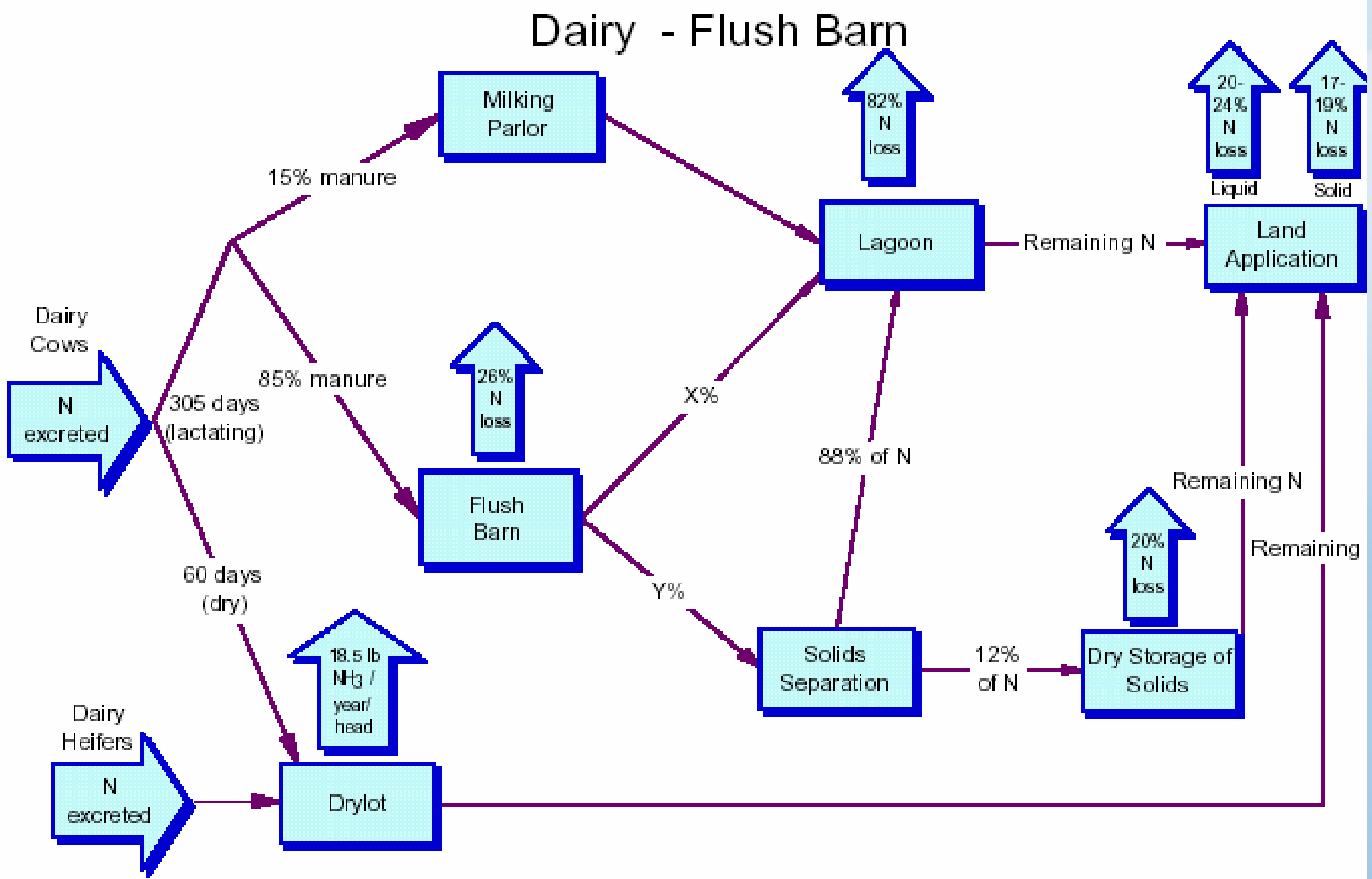
Step 2: Manure Management Trains

- 15 MMT’s plus permutations (similar to “model farms” used in past approaches)
  – e.g., housing, waste storage, land application type
  – Non-feedlot outdoor confinement (e.g., pasture) is one of the trains for swine, dairy, and beef
  – MMT’s represent different pathways for escape of ammonia to the air
  – MMT “mix” varies by state

Step 2: Manure Management Trains (cont'd)

- Animal populations, etc., are allocated among the applicable trains
- Note: Final stage in each train is usually land application

Advanced Example of Manure Management Train



The percentage of nitrogen lost is calculated based on the amount of nitrogen managed in that component.
The amount of nitrogen leaving the solids separator is based on the amount of nitrogen managed in the separator.
X% and Y% vary by size of operation, and represent the proportion of production using each type of system.

Step 3: Nitrogen Excreted

- Determine typical animal weights (within a type and weight range)
- Nitrogen per 1000 kg of live weight from NRCS *Agricultural Waste Management Field Handbook*
- Local agriculture experts could help improve this (feed is very important)
  - Land Grant University Researchers / Extension Agents

Step 4: Emission Factors

- Select the emission factor for each stage of each manure management train
  - Some are based on lbs/animal, some are percent air release of input ammonia
  - Both determine ammonia transferred to next stage
  - Some factors based on actual air testing
- Air emissions can never be higher than original manure nitrogen content
- Using stage-specific emission factors allows for applying temporal profiles and process-related variability later

Hint: Be Careful of Terms and Custom!

- Emission factors are based on using inventory or head count numbers
- Do not confuse with numbers produced or sold (river/lake analogy) – animals living at any one time vs. number slaughtered in a given year
- Cattle in feed lots may not be counted as part of state herd statistics in some state data
- New PM guidance for animal husbandry in CA in WRAP fugitives manual
- Scrounge through all possible sources for factors, including EPA studies underway, recent conferences, individual researchers (e.g., WRAP reports), etc. Current status does not always result in one single source of best emission factors and supporting data for any given source and parameters

Step 5: Apply for Target Year

- Track ammonia release through each MMT for each animal type, then calculate air releases and transfer to next stage
- Assume no air emission controls
- Add control assumptions later, and determine downstream consequences
- Sum emissions by animal type and county
- Preserve databases with full detail for transparency and later revisions

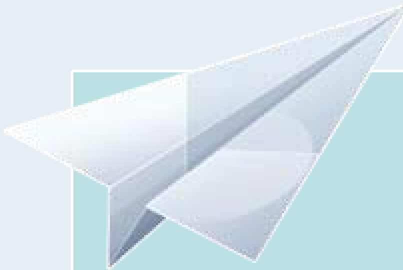
Step 6: Future Years Projections

- 2011, 2014, 2017, 2020, and 2030?? TBD by EPA-later
- USDA and Food and Agricultural Policy Research Institute – data source
- Account for past observed cyclical populations
- State-by-state population pattern changes

Comparison of 1999 and 2002 Ammonia NEIs (for illustration)

Animal Group0	1999 NEI			2002 NEI		
	Population	Emission Factor lb/head /yr	Emissions Tons/year	Population	Emission Factor lb/head /yr	Emissions Tons/year
Cattle and Calves Composite	100,126,106	50.5	2,476,333	100,939,728	23.90	1,205,493
Hogs and Pigs Composite	63,095,955	20.3	640,100	59,978,850	14.32	429,468
Poultry and Chickens Composite	1,754,482,225	0.394	345,325	2,201,945,253	0.60	664,238
Total	1,917,704,286	N/A	3,461,758	2,362,863,831	N/A	2,299,199

Ohio Ammonia Emissions: NEI 2005

	Animal Husbandry	Fertilizer Application
Ohio	57,512 (2.7%)	41,406 (3.6%)
US Total	2,115,449	1,142,409
	Tons/Year	

Ongoing - Additional NEI Improvements

- Plans to incorporate emission estimates for sheep, ducks, goats, and horses, but of little relative consequence
- Determine most recent manure production and excretion rate data by animal type and weight
- Develop ways to better address spatial, seasonal, and regional differences in emissions

ERTAC - Agricultural Ammonia Studies

- Eastern Regional Technical Advisory Committee – (ERTAC) to improve process-based emissions model – begun in 2005 by ISSRC/Environ - with RPO funding at UC-Davis www.ertac.us
- Improvements include
  - Newer science
  - 2007 Census of Ag data
- Remaining shortcomings...
  - Lots of national defaults and not much local data
- To do…
  - Identify variables model is most sensitive to
  - Compare model results to measurement studies

CMU Model

- **Carnegie Mellon University (CMU)** developed a recommended model (Version 3.6) for estimating ammonia emissions from
  - agricultural activities (including fertilizer application), and soils
  - wastewater treatment
  - wildfires
  - domestic and wild animals
  - transportation sources
  - industrial activities
  - others

  http://www.cmu.edu/ammonia/ to download the CMU model and get details on recent model improvements

CMU Model (cont'd)

- Activity Data in CMU v3.6 is year 2002
- CMU Model allows update of activity and emission factor data
- Pechan recently developed activity inputs for 2007 for Livestock and Crop Fertilizer using the same data sources as CMU v3.6
- Livestock
  - USDA, 2007 Census of Agriculture
- Crop Fertilizer
  - Association of American Plant Food Control Officials, Commercial Fertilizers 2007

Use recent existing "accepted" information and proportionally update/adjust by animal counts where it makes sense – Don't reinvent the wheel! Try to assure that haze SIP data are consistent.

Questions?

Comments?

Discussion?

Preparation of Fine Particulate Emissions Inventories

Chapter 9 – Combustion Nonpoint Sources

What We Will Cover

- Residential Wood Combustion
- Residential Open Burning
- Land Clearing Debris Burning
- Agricultural Burning
- Wildland Fire Emissions

2005 Ohio $PM_{2.5}$ Emissions (TPY)

	Wildland Fires *2002	Ag. Field Burning	Res. Waste Open Burning	Land Clearing Debris Open Burning	Res. Wood Comb
Ohio		NA	7,122	3,494	8,936
US	1,100,000	224,681	133,600	114,383	381,780

Residential Wood Combustion

- What you will learn:
  - Basis of the NEI estimates
  - Suggestions for making improvements in your airshed

MANE-VU 2002 RWC Emission Inventory

- Objective
  - Prepare 2002 EI based on survey of household equipment usage and wood consumption patterns
- Survey Method – stratified, random-sampling
- Data Collected for Each Household
  - Wood consumption at equipment level (both real wood and artificial logs)
  - Wood type for real wood
  - Temporal activity to calculate monthly, weekly, and daily emissions

Sample Frame Construction

- Sampling designed to address major sources of variability in activity (i.e., wood consumption)
- Sources of variability include:
  - Location and type of housing
  - Heating demand (expressed as heating degree days (HDDs))
  - Availability of wood

Sample Frame Construction (cont'd)

- Sample Stratification
  - Housing Data – 2000 Census tract data used to stratify sample by:
    - Urban, suburban, and rural single-family and “other” homes (other homes = multi-family units such as apartments, condos, mobile homes)
    - Rural category stratified by forested and non-forested areas using USGS GIS data (i.e., Forest Fragmentation Index Map of North America)
  - Heating Demand – Total annual HDDs used to stratify sample into 3 zones

Sample Frame

Geographic Zone	Rural-Forested Single-Family	Rural-Forested Other	Rural-Non-Forested Single-Family	Rural-Non-Forested Other	Suburban Single-Family	Suburban Other	Urban Single-Family	Urban Other
High HDD	Cell 1 61 (173)	Cell 2 61 (64)	Cell 3 61 (87)	Cell 4 61 (66)	Cell 5 61 (61)	Cell 6 61 (72)	Cell 7 61 (69)	Cell 8 61 (69)
Low HDD	Cell 9 61 (150)	Cell 10 61 (62)	Cell 11 61 (118)	Cell 12 61 (69)	Cell 13 61 (76)	Cell 14 61 (67)	Cell 15 61 (75)	Cell 16 61 (62)
Med HDD	Cell 17 61 (87)	Cell 18 61 (60)	Cell 19 61 (91)	Cell 20 61 (64)	Cell 21 61 (71)	Cell 22 61 (60)	Cell 23 61 (63)	Cell 24 61 (68)

Survey Instrument

- Questionnaire developed to gather activity data for:
  - Indoor equipment (fireplaces, woodstoves, pellet stoves, furnaces, and boilers)
  - Outdoor equipment (fire pits, barbeques, fireplaces, and chimineas)
- Pilot survey performed to test the instrument
- Survey conducted using computer-assisted telephone interviewing
  - Completed 1,904 surveys across all 24 cells

Survey Data Reduction/Analysis

- QA reviewed each survey
- Calculated/summarized for each cell:
  - User fraction (fraction of total household population that burns wood in indoor and outdoor equipment)
  - Annual activity (cords of wood by equipment and wood types)
  - Temporal data
- Conducted statistical analyses to identify significant differences between cells for:
  - User fraction
  - Annual Activity

Indoor Wood-Burning Equipment Preliminary Survey Results (% Burners)

Geographic Zone	Rural-Forested		Rural-Non-Forested		Suburban		Urban	
	Single-Family	Other	Single-Family	Other	Single-Family	Other	Single-Family	Other
High HDD	Cell 1 FP= 34 WS= 67 F/B= 21 PS= ***4***	Cell 2 FP= 75 WS= 75 F/B= 0 PS= 0	Cell 3 FP= 43 WS= 76 F/B= 7 PS= 0	Cell 4 FP= 33 WS= 67 F/B= 0 PS= 0	Cell 5 FP= 36 WS= 64 F/B= ***18*** PS= 0	Cell 6 FP= 0 WS= 0 F/B= 0 PS= 0	Cell 7 FP= 80 WS= 30 F/B= 0 PS= 0	Cell 8 FP= 100 WS= 0 F/B= ***50*** PS= 0
Low HDD	Cell 9 FP= 60 WS= 65 F/B= 5 PS= ***2***	Cell 10 FP= 100 WS= 0 F/B= 0 PS= 0	Cell 11 FP= 61 WS= 54 F/B= ***4*** PS= 4	Cell 12 FP= 50 WS= 50 F/B= 0 PS= 0	Cell 13 FP= 70 WS= 35 F/B= 0 PS= 5	Cell 14 FP= 67 WS= 0 F/B= 0 PS= 33	Cell 15 FP= 90 WS= 10 F/B= 0 PS= 0	Cell 16 FP= 100 WS= 0 F/B= 0 PS= ***20***
Med HDD	Cell 17 FP= 55 WS= 66 F/B= 7 PS= 7	Cell 18 FP= 60 WS= 60 F/B= 0 PS= 0	Cell 19 FP= 59 WS= 45 F/B= 0 PS= 9	Cell 20 FP= 100 WS= 0 F/B= 0 PS= ***25***	Cell 21 FP= 81 WS= 27 F/B= ***8*** PS= 4	Cell 22 FP= 50 WS= 50 F/B= 0 PS= 0	Cell 23 FP= 100 WS= 0 F/B= 0 PS= 0	Cell 24 FP= 0 WS= 0 F/B= 0 PS= 0

FP = fireplace; WS = woodstove; F/B = furnace/boiler; PS = pellet stove; Totals do not always add to 100 since some respondents use more than one type of equipment. Values in ***bold italics*** are derived from responses that were identified as wood consumption outliers (equipment could be miss-categorized by the respondent).

Preliminary Results/Observations

- Indoor Equipment
  - Geographic distribution of equipment
    - Rural Areas:
      - Higher diversity of equipment types than in urban areas
      - Higher percentage of stoves and furnaces than in urban areas
    - Urban/Suburban Areas:
      - Lower diversity of equipment types than in rural areas
      - Higher percentage of fireplaces than in rural areas
  - Heating Demand
    - High HDD Zone:
      - Rural Areas – higher percentage of stoves and furnaces
    - Low HDD Zone:
      - Rural Areas – higher percentage of fireplaces

Preliminary Results/Observations (cont'd)

- Indoor Equipment
  - For urban areas, it was difficult to find households that burned wood for the sample size taken
  - The urban sample size was not increased because of budget constraints **and** priorities for obtaining a representative sample for three instead of two HDD zones
  - The equipment- and fuel-based survey results were used to estimate emissions (e.g., lbs $PM_{2.5}$/household-yr) for each household surveyed
  - A household-based statistical model is being developed to estimate emissions for each cell

Preliminary Results/Observations (cont'd)

- Outdoor Equipment
  - Equipment-based emissions will be estimated using survey results

Annual Emissions = Fraction of outdoor equipment users per cell x annual activity x emission factor

Emission Inventory Development

- Emissions were:
  - Estimated for all criteria pollutants/precursors and several dozen toxic air pollutants
  - Estimated at the census tract level (summed to county, state, region)
  - Temporally allocated to support modeling using profiles developed from the survey

Lessons Learned

- Survey Instrument: for regional surveys, tailor it to suit the usage patterns in rural, suburban, urban areas
- Difficult to find wood burners in urban areas
  - minimum sample sizes need to reflect this

Lessons Learned (cont'd)

- For indoor equipment, to keep resources manageable:
  - Consider the use of a statistically-derived emissions-based model (household level) instead of an equipment-specific method
  - Concern: Approach aggregates emissions for different types of wood burning equipment needed to support control measure analysis

Documentation for MANE-VU EI

Final Report: MANE-VU Residential Wood Combustion Emission Inventory (June 22, 2004)

http://www.marama.org/visibility/ResWoodCombustion/Final_report.pdf

How are RWC Emissions Estimated in the 2005 and 2008 NEI?

- Uses new RWC emissions tool
- MS Access tool
- Uses available activity and emission factor data
- Users can update values for their states/counties
- Produces county-level emission estimates

How are RWC Emissions Estimated in the 2005 and 2008 NEI? (cont'd)

- Pollutants
  - PM_{10}-PRI, $PM_{2.5}$-PRI, NO_x, CO, VOC, SO_x
  - HAPs (number of pollutants)

Estimating RWC Emissions

$$E_y = (n*b*d)*EF_y*CF_y$$

n = number of appliances

b = burn rate of appliance cords of wood burned /yr

d = wood density, converts cords of wood burned to tons of wood burned

EF = emission factor lbs pollutant / ton of dry wood burned

CF = control factor

Emission Factors for Fireplaces Without Inserts (lbs pollutant/ton of dry wood)

- NO_x, SO_x, VOC, & HAPs
  - AP-42, Chapter 1.9, Table 1.9-1
  - Substituted lower VOC factor from MANE-VU
- PM_{10}-PRI, $PM_{2.5}$-PRI, & CO
  - Houck, J.E., et al, “Review of Wood Heater and Fireplace Emission Factors,” NEI Conference, May 1-3, 2001
  - Based on test data more current than AP-42
  - $PM_{2.5}$-PRI assumed to be same as PM_{10}-PRI

Emission Factors for Wood Stoves & Fireplaces With Inserts (lbs pollutant/ ton of dry wood)

- Criteria Pollutants: AP-42, Chapter 1.10, Table 1.10-1
  - PM_{10}-PRI, $PM_{2.5}$-PRI, & CO EFs are average for all wood stoves
  - $PM_{2.5}$-PRI assumed to be same as PM_{10}-PRI
- HAPs: AP-42, Chapter 1.10, Tables 1.10-2, -3, & -4
  - AP-42 EFs for Polycyclic Aromatic Hydrocarbons (PAH) reduced by 62% based on recent test data (Houck, et al, 2001)
- Conversion Factor: One cord of wood equals 1.163 tons

RWC SCCs Included in EPA Model

SCC	Appliance Type
2104008100	Fireplace: General
2104008210	Wood Stove: Fireplace inserts, non-EPA certified
2104008220	Wood Stove: Fireplace inserts, EPA certified, non-catalytic
2104008230	Wood Stove: Fireplace inserts, EPA certified, catalytic
2104008310	Wood Stove: Freestanding, non-EPA certified

RWC SCCs Included in EPA Model (cont'd)

SCC	Appliance Type
2104008320	Wood Stove: Freestanding, EPA certified, non-catalytic
2104008330	Wood Stove: Freestanding, EPA certified, catalytic
2104008510	Furnace: Indoor, cordwood-fired, non-EPA certified
2104008610	Wood Hydronic Heater: Outdoor
2104009000	Firelog Total: All combustor types

Activity Data

Method 1: Applies to fireplaces, inserts, and wood stoves

$$U = P * AP * BR * D$$

where: P = number of 2005 occupied housing units by county

AP = percentage of occupied housing units for a specific appliance category

BR = burn rate (cords/year)

D = average wood density

Activity Data

Method 2: Applies to outdoor hydronic heaters, indoor furnaces, and pellet stoves

$$U = AN * BR * D$$

where: AN = number of appliances by county

BR = burn rate (cords/year)

D = average wood density

Method 1 - American Housing Survey Data Example - Midwest Region for 2005

Equipment	Stoves	Fireplaces with Inserts	Fireplaces without Inserts
Main Heating	143	22	0
Parallel Heating	181	99	70
Supplemental Heating	635	829	643

Percentage of Occupied Housing Units by Appliance for Midwest States

Heating Category	Appliance Type	Percentage of Units with this Appliance
Main Heating	Wood Stove	0.57%
Main Heating	Fireplace with Inserts	0.09%
Main Heating	Fireplace without Inserts	0.00%
Pleasure Heating	Wood Stove	0.73%
Pleasure Heating	Fireplace with Inserts	0.40%
Pleasure Heating	Fireplace without Inserts	0.28%
Secondary Heating	Wood Stove	2.54%
Secondary Heating	Fireplace with Inserts	3.32%
Secondary Heating	Fireplace without Inserts	2.58%

Burn Rates

- Cords of wood burned per year
- National average rates from Midwest/Plains state surveys
- Vary by appliance type
- Vary by burn purpose
- Climate zones used to adjust burn rates
  - Climate zone 1 includes AK, MT, WY, ND, SD, and most of ID
  - Adjustment based on average Btus for heating

Wood Density (lbs/ft^3)

- Burn rate data in cords (volume unit) and emission factors in tons of oven-dried wood (mass unit)
- Timber Products Output database, US Forest Service
  - County level database
  - Survey results of sawmill operators that provides volume of wood by species for several different categories of use, one of the uses being fuel wood
  - Used averages where no county sawmill data available
  - Assumed 80 ft^3/cord to account for airspaces

Method 2 - Outdoor Hydronic Heaters

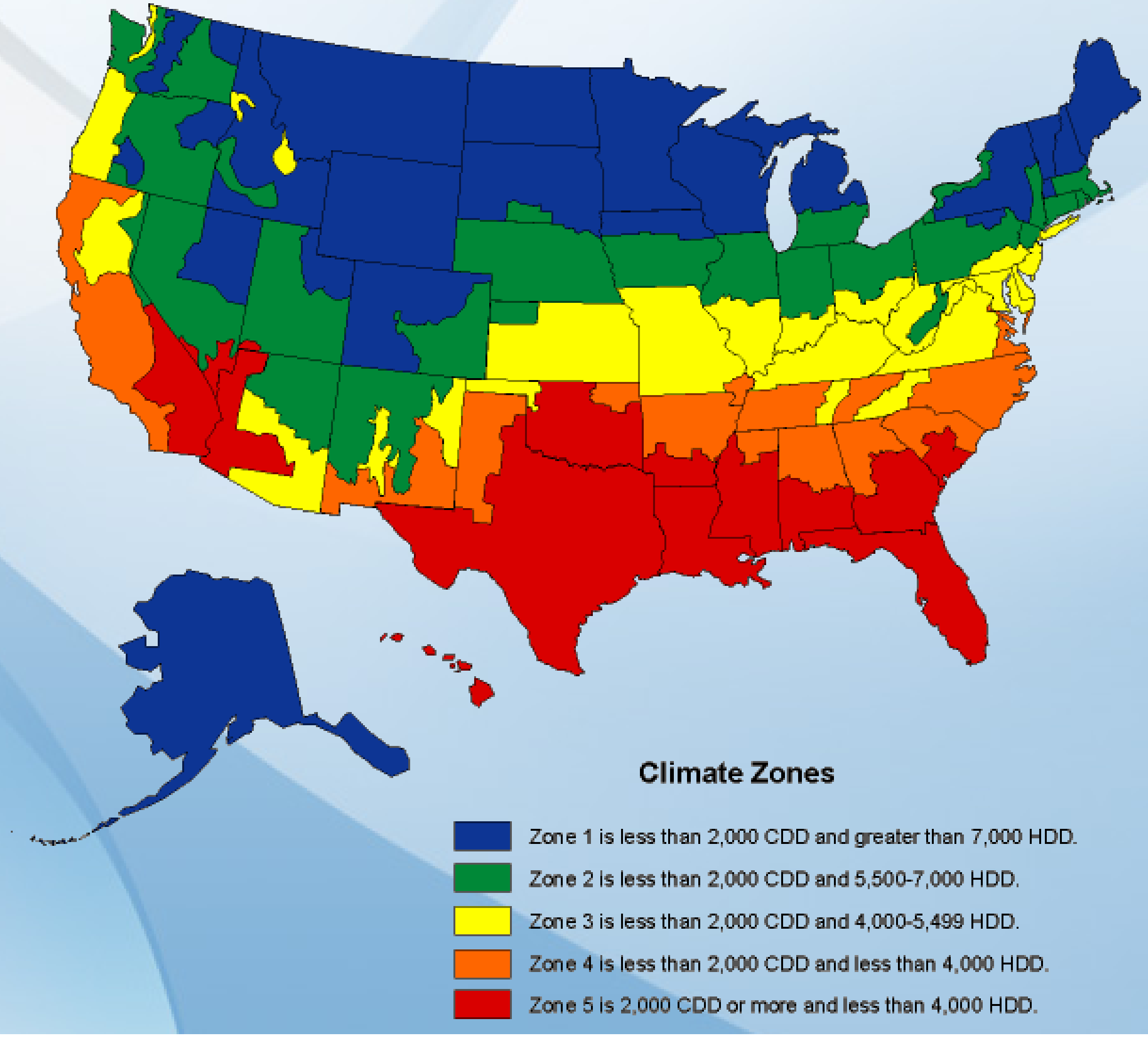
- 50 state sales data from Hearth, Patio and BBQ Association covers 1990-2005 sales
- County allocations according to wood stove populations
- None allocated in Metropolitan Statistical Areas

Indoor Furnaces

Regional approaches to estimating county-level appliance populations

Region	Source
MANE-VU	MANE-VU survey
Great Lakes	Minnesota DNR study
Northwest	Oregon DEQ study
South	No furnaces in zones 4 and 5

U.S. Climate Zone Map



MANE-VU

- Study provides number of centralized heaters/furnaces by state
- This includes indoor plus outdoor
- Subtract NESCAUM study estimates for OHH
- State:county allocation by woodstove populations

Great Lakes States

- MN study estimated furnace populations for five regions
- MN region to county allocations per wood stoves
- Other states – 38 furnaces per 100 wood stoves

Northwest

- Oregon DEQ study (2000)
- This yielded a ratio of furnaces to wood stoves
- Applied in other NW states to determine furnace populations
- 5.3 indoor furnaces to 100 wood stoves

Burn Rates

- Entries contain:
  - burn profile
  - SCC
  - burn purpose
  - cords burned per year per appliance

County Populations

- Entries contain:
  - county
  - number of occupied housing units in 2005
  - appliance profile
  - burn profile
  - climate zone

Appliance Profiles

- Entries contain:
  - appliance profile
  - SCC
  - burn purpose (main, secondary, or pleasure)
  - percentage of households with an appliance of the type corresponding to the SCC

Density by County

- Entries contain:
  - county
  - density in lbs/ft^3
  - density in tons/cord
  - data source

Other Appliance Populations

- Entries contain:
  - county
  - SCC
  - burn purpose
  - number of appliances in the county with an appliance of the type corresponding to the SCC

Emission Factor by SCC

- Entries contain:
  - SCC
  - pollutant
  - emission factor with units
  - emission factor converted to tons pollutant/tons of wood combusted
  - data source for the emission factor

How Can You Improve the NEI for Your Area?

- Preferred Method: Residential Wood Survey
  - Obtain locally representative information on the amount of wood fuel use specifically for wood stoves & fireplaces (with and without inserts)
  - This will require a local survey, or activity data generated by state & local governments
  - Reduces uncertainties in estimates associated with allocating national activity to counties

How Can You Improve the NEI for Your Area? (cont'd)

- Rule Effectiveness/Rule Penetration
  - Incorporate effects of S/L/T rules and level of compliance
  - NEI methodology does not account for S/L/T rules

Residential Open Burning

Residential (Household) Municipal Solid Waste

Yard Waste
(Leaves & Brush)

Residential Open Burning - What Sources are Included?

SCCs:

2610030000 - Residential Municipal Solid Waste (MSW) Burning

Pollutants: PM_{10}, $PM_{2.5}$, CO, NO_x, VOC, SO_2, 32 HAPs

2610000100 - Residential Leaf Burning

2610000400 - Residential Brush Burning

Pollutants: PM_{10}, $PM_{2.5}$, CO, VOC, 6 HAPs

Details:

http://www.epa.gov/ttn/chief/net/2002inventory.html#documentation

Residential Open Burning - NEI Methods for Residential MSW and Yard Waste

$$E = A * EF * (1 - CE * RP * RE)$$

where:
- E = Controlled Emissions, lbs pollutant per year
- A = Activity, tons of MSW or leaves/brush burned per year
- EF = Emission Factor, lbs per ton burned
- CE = % Control Efficiency/100
- RP = % Rule Penetration/100
- RE = % Rule Effectiveness/100

100% CE assumed for counties where urban population exceeds 80% of the total population

Assumed 100% RE and RP

All other counties, assumed 0% CE, RE, and RP

Note: Emission factors are found in Appendix A of

http://www.epa.gov/ttnchie1/net/2002inventory.html

Residential Open Burning - NEI Methods for Residential MSW

- Activity Data (tons of waste burned)
- Step 1 - Estimate 2002 rural population by county
  - County-level rural population estimated by applying rural/urban percentages from 2000 Census data to 2002 population
- Step 2 - Multiply per capita waste factor by rural population
  - Used national average per capita waste generation factor of 3.37 lbs/person/day (noncombustibles and yard waste subtracted out)

Residential Open Burning - NEI Methods for Residential MSW (cont'd)

- Step 3 - Estimate amount of waste burned
  - Assume 28% of total waste generated is burned (default)
- Step 4 - Account for burning bans
  - For counties where urban population exceeds 80 percent of the total population, the amount of waste burned was assumed to be zero, therefore zero open burning assigned to these counties

Residential Open Burning - NEI Methods for Residential Yard Waste

Activity Data

(tons of yard waste burned)

- Step 1 - Estimate 2002 rural population by county
  - County-level rural population estimated by applying rural/urban percentages from 2000 Census data to 2002 population

Residential Open Burning - NEI Methods for Residential Yard Waste (cont'd)

- Step 2 - Multiply per capita waste factor by rural population
  - Used national average per capita yard waste generation factor of 0.54 lbs/person/day
- Step 3 - Estimate amount of leaf, brush and grass yard waste
  - Multiply total yard waste mass by 25% to estimate leaf waste, 25% for brush waste, and 50% for grass waste
- Step 4 - Estimate amount of waste burned
  - Assume 28% of total leaf and brush waste generated is burned; assume 0% of grass is burned

Residential Open Burning - NEI Methods for Residential Yard Waste (cont'd)

- Step 5 - Adjust for variation in vegetation
  - Used the following ranges to make adjustments to the amount of yard waste generated per county:

Percent forested acres per county	Adjustment for yard waste generated
< 10%	Zero out
>=10%, and <50%	Multiply by 50%
>=50%	Assume 100%

Residential Open Burning - NEI Methods for Residential Yard Waste (cont'd)

- Step 6 - Account for burning bans
  - For counties where urban population exceeds 80 percent of the total population, the amount of waste burned was assumed to be zero, therefore zero open burning assigned to these counties

Residential Open Burning - MANE-VU Example

- Development of 2002 residential open burning inventory for MANE-VU states
- Multi-state RPO developed inventory following EIIP procedures

Residential Open Burning - MANE-VU Example (cont'd)

- Developed survey instrument to collect:
  - Number/percentage of households that burn waste
  - Burn frequency
  - Amount per burn
  - Seasonal activity
- 3 separate surveys for:
  - Residential MSW
  - Brush
  - Leaf

Residential Open Burning - MANE-VU Example (cont'd)

- Survey results were used to estimate emissions for each survey jurisdiction
- For non-surveyed areas, default activity data derived from survey responses were applied

Residential Open Burning - MANE-VU Example (cont'd)

To estimate the mass of waste burned for residential MSW and yard waste, the following equation was used:

$$Wt = HH * Bt * M$$

where:
- Wt = Mass of waste burned per time period
- HH = Number of households that burn
- Bt = Number of burns per time period
- M = Mass of waste per burn

Residential Open Burning - MANE-VU Example (cont'd)

- Developed database of area-specific control efficiency (CE), rule penetration (RP) and rule effectiveness (RE)
- Performed rule effectiveness (RE) survey to determine level of compliance with state or local open burning prohibitions
- To estimate default RE values, the survey data was statistically analyzed resulting in one value for all non-surveyed areas

Residential Open Burning - MANE-VU Example (cont'd)

- Emissions estimated for all criteria pollutants/precursors and several toxic air pollutants
- Emissions estimated at the census tract level (summed to county, state, region)
- Emissions temporally allocated to support modeling using profiles developed from the survey

Lessons Learned

- If leaf burning is significant, perform separate surveys in targeted areas for leaf waste and brush waste burning
- Perform MSW surveys separate from yard waste surveys, instead of combined to reduce survey length
- A larger sample may have allowed for greater geographic distinction

Lessons Learned (cont'd)

- Sub-county emissions estimates serve as the basis for a more spatially refined inventory
- Regional survey provides greater consistency
- Better accounting of controls results in decreased emissions relative to NEI

Residential Open Burning - Improvements to NEI Methods

- Review EIIP Volume III, Ch. 16 Open Burning
- Obtain state/local estimates of per-capita waste generation
- Use state/local estimates for amount or percentage of waste burned
- Obtain state/local estimates of months when yard wastes are burned

Residential Open Burning - Improvements to NEI Methods (cont'd)

- Data Sources
  - Local or State Solid Waste Agency
  - Air Agency
  - County Health Department
  - State or National Solid Waste Management Organizations
  - Local Survey

Residential Open Burning - Improvements to NEI Methods (cont'd)

- Identify rules prohibiting or limiting open burning, and the organization that enforces those rules
- For areas that have burning prohibitions, consider performing rule effectiveness (RE) surveys
- Level of enforcement/compliance can be a significant variable in calculating controlled emissions
- Rule penetration (RP) to reflect duration of seasonal bans relative to annual activity profile, exempt activities

Questions?

Land Clearing Debris Burning

Land Clearing Debris Burning - What Sources are Included?

SCCs:

2610000500 - Land Clearing Debris Burning

Pollutants: PM_{10}, $PM_{2.5}$, CO, VOC, 6* HAPs

*There are multiple HAPs likely emitted from debris burning which have not been fully assessed and will likely vary depending on debris content. The key HAPs used by EPA for risk assessment are identified as top priority for reporting.

Land Clearing Debris Burning - NEI Method (cont'd)

Emission Calculation

$$E = A * LF * EF$$

where: E = Emissions, lbs pollutant per year

A = No. of acres of land cleared per county (residential + commercial + road construction)

LF = County-specific loading factor, tons per acre

EF = Emission factor, lbs pollutant per ton

Represents an upper-bound emissions estimate

Assumes all fuel loading on land cleared is burned; no controls or bans

Land Clearing Debris Burning – NEI Method

Activity Data

- Estimate the county-level total number of acres disturbed by residential, non-residential and roadway construction – same fundamental approach for each
  - May use number of acres disturbed from fugitive dust construction emissions calculations
- Apply loading factor to number of acres to estimate the amount of material or fuel subject to burning

Land Clearing Debris Burning - NEI Method (cont'd)

- Weighted, county-specific loading factors developed based on acres of hardwoods, softwoods, and grasses (BELD2 database in BEIS) http://www.epa.gov/asmdnerl/biogen.html
- Multiply average loading factors by percent contribution of each type of vegetation class to the total county land area

Land Clearing Debris Burning - NEI Method (cont'd)

Average loading factors for hardwood and softwood are then further adjusted by 1.5x to account for mass of tree below the surface

Fuel Type	Fuel Loading (tons/acre)
Hardwood	99
Softwood	57
Grass	4.5

Land Clearing Debris Burning - NEI Method (cont'd)

Fuel Loading Factor Equation

$$L_w = F_h*L_h + F_s*L_s + F_g*L_g$$

where: L_w = County-specific weighted loading factor

F_h = Fraction of county acres classified as hardwoods

L_h = Average loading factor for hardwoods

F_s = Fraction of county acres classified as softwoods

L_s = Average loading factor for softwoods

F_g = Fraction of county acres classified as grasses

L_g = Average loading factor for grasses

Land Clearing Debris Burning - Northern Virginia **Example**

- Performed Rule Effectiveness (RE) survey to determine the level of compliance for:
  - Land clearing/debris burning
  - Residential waste burning
- Developed RE to apply to ozone season open burning emission estimates for the Virginia portion of the Washington DC-MD-VA Ozone Nonattainment Area

Land Clearing Debris Burning - Northern Virginia Example (cont'd)

- Reviewed conditions of existing open burning rules
  - Time period of ban(s)
  - Exemptions and special provisions
- Surveyed local open burning officials responsible for tracking and enforcing open burning rules

Land Clearing Debris Burning - Northern Virginia Example (cont'd)

- Started with EPA questionnaire from RE guidance, modified for open burning
- Responses to questions are assigned specific point values that add up to a maximum of 100 points, considered equivalent to a RE percentage value

Land Clearing Debris Burning - Northern Virginia Example (cont'd)

- RE values analyzed by county and for 5-county region
  - Resulting regional RE estimate of 93 percent
- If area comprised of counties and jurisdictions with significantly different population densities, one should analyze responses by urban and rural areas

Land Clearing Debris Burning - Improvements to NEI Method

- Review EIIP section on Open Burning http://www.epa.gov/ttnchie1/eiip/
  - EIIP Volume III, Ch. 16
  - Preferred methods rely on direct measure of mass of waste or debris burned
  - Mass amounts may be available from estimates in permits issued
- Review & improve estimates of the acres cleared based on local air and fire inspectors
- Develop improved estimate of the "average loading factor"

Land Clearing Debris Burning - Improvements to NEI Method (cont'd)

- Identify specific counties with burning bans, and specification of counties where wastes are burned - all states have differences
- State or local estimates of the percentage or amount of waste burned per construction event

Questions?

Agricultural Burning

Agricultural Burning ~ SCC 2801500000 - What We Will Cover

- General Methodology
- Wheat Stubble Example
- Potential Improvements to NEI

Agricultural Burning – General Methodology

- Activity – Acres of crop burned from burn permits or other resource
- Fuel Loading Factor (Tons/Acre)

  http://www.arb.ca.gov/ei/see/memo_ag_emission_factors.pdf

  http://www.epa.gov/ttn/chief/ap42/ch02/final/c02s05.pdf
- Emission Factor (lb/Ton Fuel Burned)

  http://www.arb.ca.gov/ei/see/memo_ag_emission_factors.pdf

  http://www.epa.gov/ttn/chief/ap42/ch02/final/c02s05.pdf
- Control Efficiency (CE, %)
  - WRAP's ERT (Emissions Reduction Factor) work may be useful

  http://www.wrapair.org/forums/fejf/documents/ert/index.html

*Emissions = Activity * Fuel Load * EF * (1-CE)/2000*

~ Note: NEI methods in need of review & update ~

Wheat Stubble Burning Example

- Method - Develop inventory using county-specific data if possible
  - Activity
    - Acres of wheat burned by month obtained from burn permits issued
    - Assume 25,000 Ac burned in March, 2008 in Smallcounty, KA
  - Fuel Loading
    - Assume 1.9 Tons Fuel per Acre burned (ref ARB – consistent w/ AP-42)
  - Emissions Factor
    - 10.1 lb $PM_{2.5}$ per Ton Fuel burned (ref ARB – consistent w/ AP-42 for backfired wheat ~ CE = 0.0 for this EF)

$PM_{2.5}$ Emissions = Activity * Fuel Load * EF * (1-CE) /2000 lb/T

$PM_{2.5}$ Emissions = 25,000 * 1.9 * 10.1 * (1-0.0) / 2000

$PM_{2.5}$ Emissions = 240 Tons $PM_{2.5}$ in 3/08 in Smallcounty KA

Note: 2008 NEI encourages emissions estimation fire-by-fire (EVENT).

Agricultural Burning - Improvements

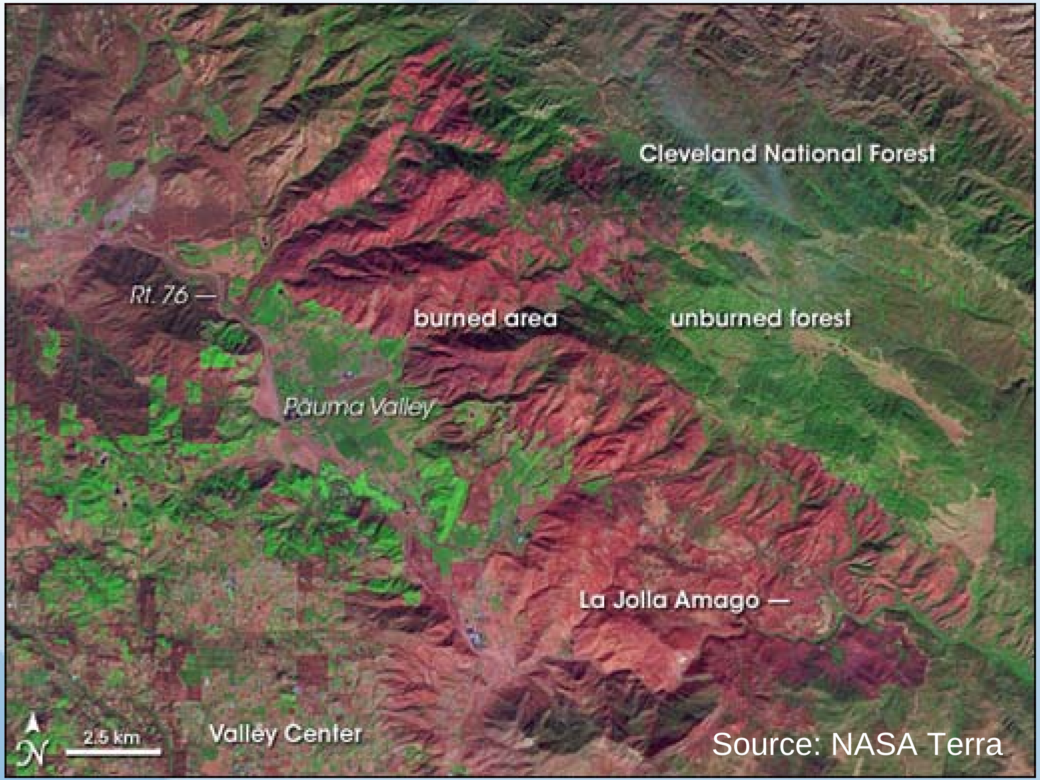
- Preferable to inventory larger fires (> 100 acres) as events with a start and stop date and time; lump smaller fires into monthly acreages
- Requires coordination with burners and permit authorities
- Start building a system and relationships with the burners/permitting authorities to enable such an inventory in the future

Agricultural Burning - Improvements (cont'd)

- Obtain local acres of crops burned data from:
  - Burn permits
  - Survey of county agricultural extension offices
  - Note: some state/tribe recordkeeping “on paper”
- Verify that burns actually occurred
- Obtain fuel loading data
  - Local data preferred from county agricultural extension offices, local Natural Resources Conservation Service Center
  - National defaults available from Chapter 2.5 in *AP-42 (Needs review/update)*

Questions?

Wildland Fire Emissions



Wildfires

Wildland Fire Use

Prescribed Fires

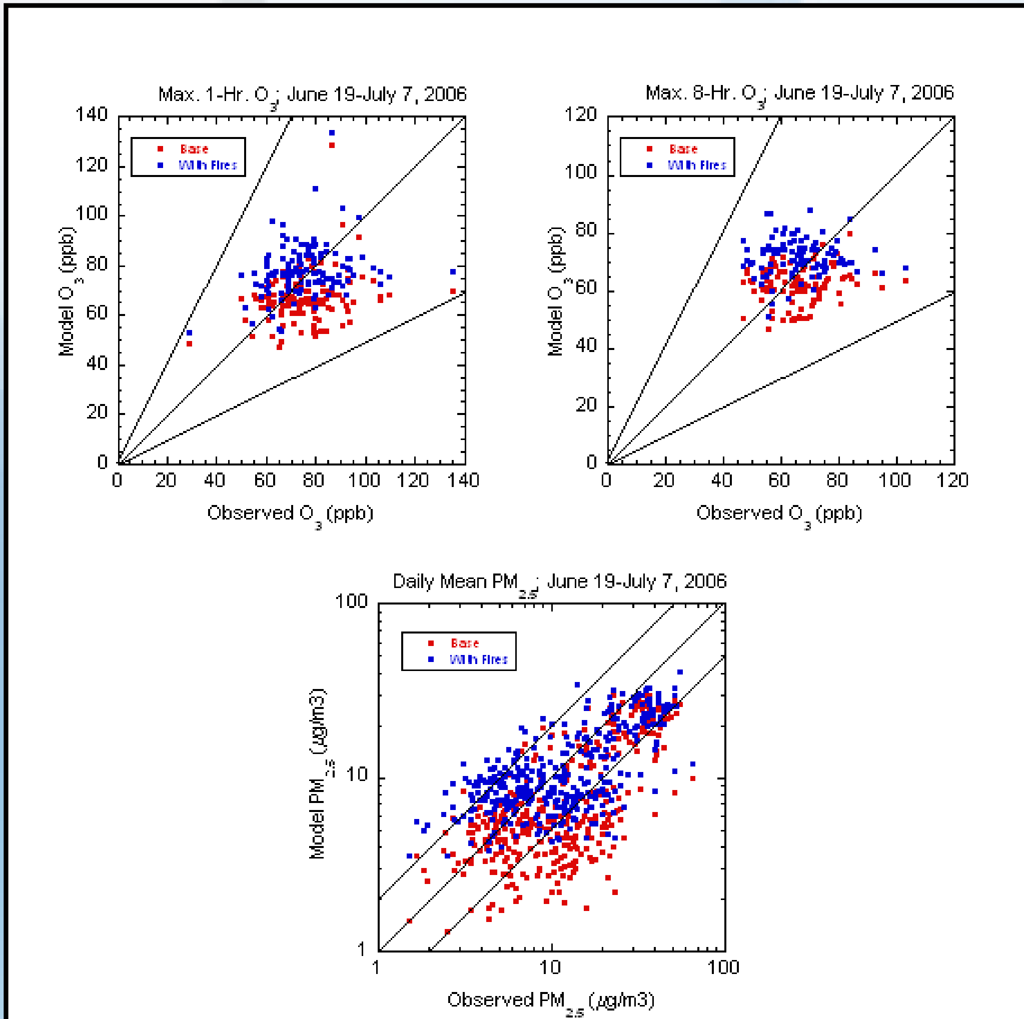
Overview of Wildland Fires

- Wildland Burning
  - Types: Wildfires, Managed (Prescribed) Burns
  - Burners:
    - NPS, USFS, BLM, USFWS, State & Tribal Forests, Private Burners
- Prescribed Burning
  - Intentionally ignited, based on met & fuel conditions
  - Used for:
    - Habitat improvement
    - Forest health
    - Managing undergrowth and understoring of the forest
    - Reducing risk of wildfires

What We Will Discuss

- Fire emissions in pre-2002 – 2008
  - Fire impacts estimated by AQ modeling
  - Evolving fire emissions estimation methods
  - SMARTFire
  - BlueSky
- Future plans
- EPA’s new ***Events Module*** for Fires in the NEI

Scatter Plots of Max 1-hr Ozone, Max 8-hr Ozone & Daily Mean $PM_{2.5}$ for June / July Episode



Model-obs. pairs selected where fire impacts were detected:

O3 (Fire-base)>4ppb

PM25 (Fire-base)> 2ug/m3

Legend
- With Fires
- Without Fires

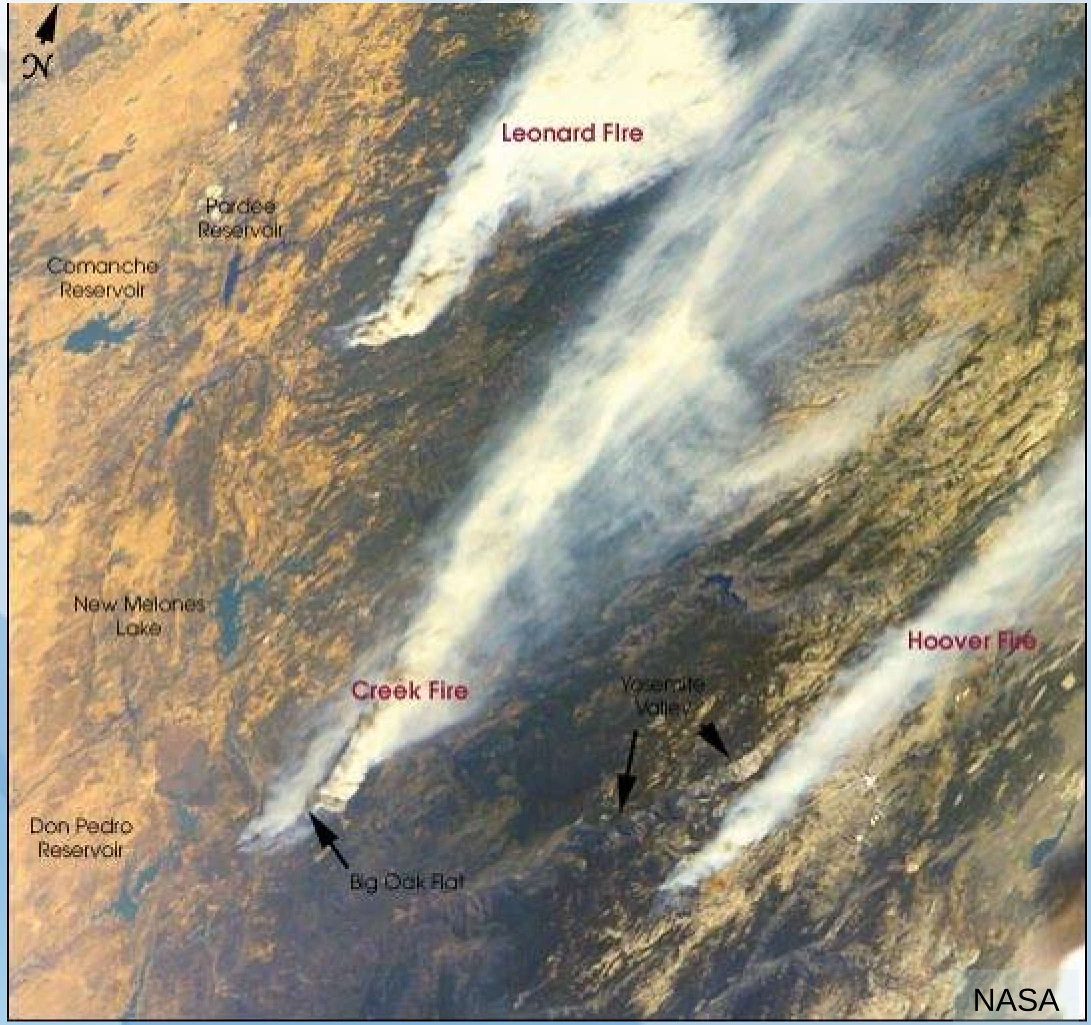
Improving the NEI's Fire EI
Evolution of the NEI for Fires

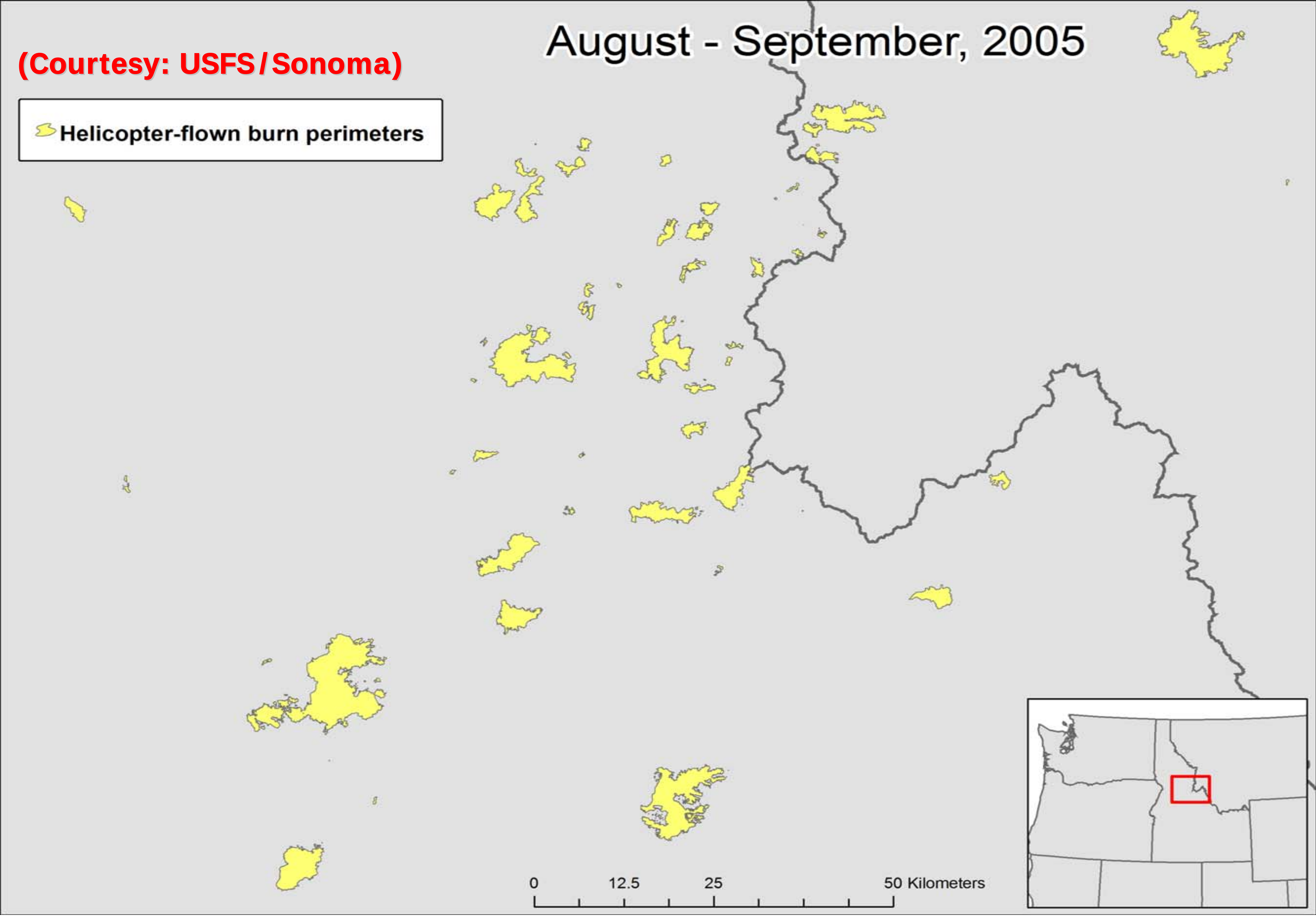
- **Pre – 2002** Fires treated as Non Point
  - – Emission Factors (AP-42)
  - – State-specific Fuel Consumed per Acre Burned
  - – Annual Activity Data ~ State (or regional) Level
    - USFS, BIA, BLM, NPS, FWS
    - Some states provide private / state burn data
    - Spatial allocation to counties using forested area
  - – Emissions Processor ~ Allocates Diurnal & Monthly
- **2002 –** Fires treated as Point Sources
  - – Average daily emissions & 1st-day-of-fire location
  - – Expensive "Snapshot" of 2002 – cost not sustainable

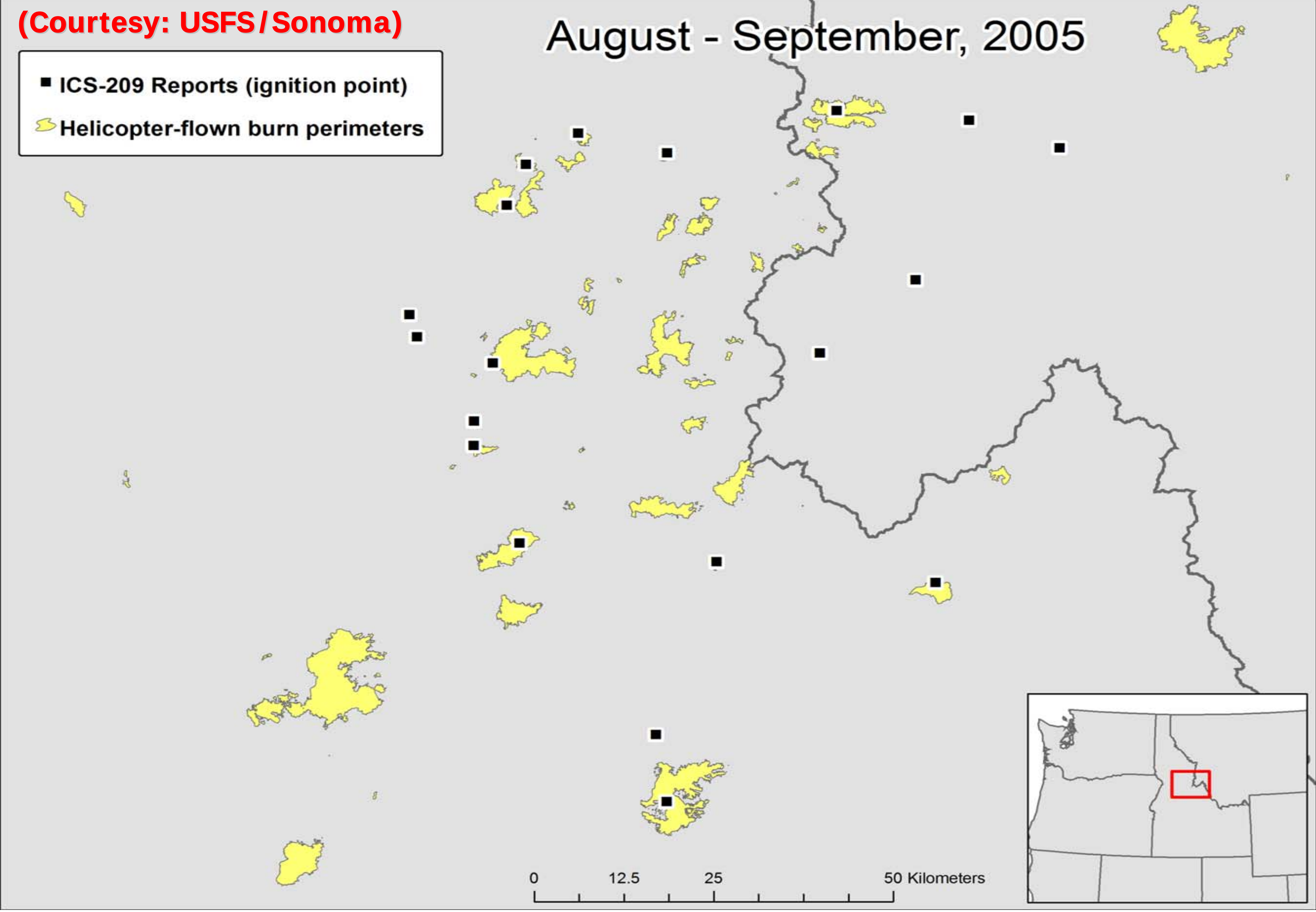
Improving the NEI's Fire EI
Evolution of the NEI for Fires (cont'd)

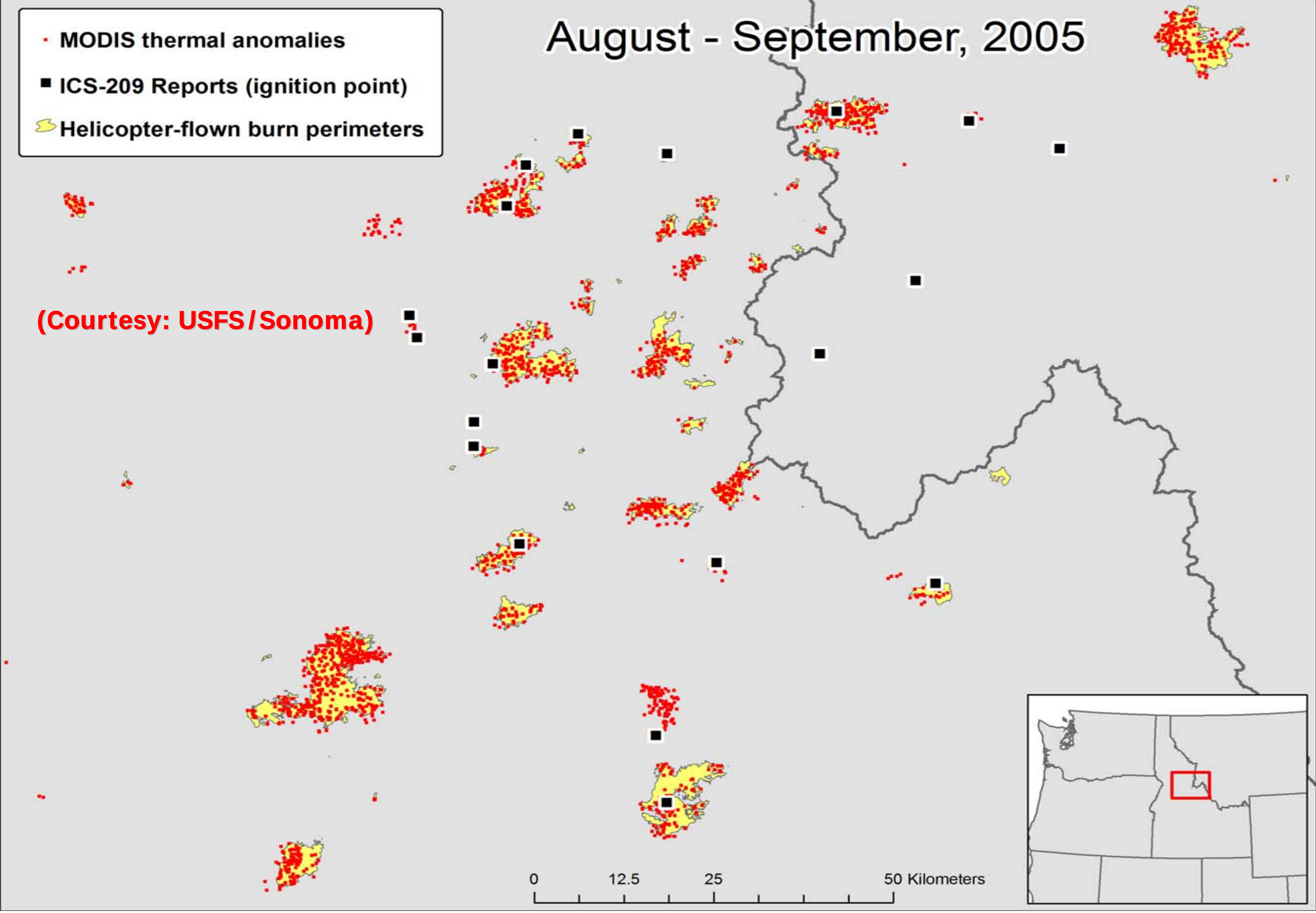
- **2003-2008v1** Fires treated as Point Sources
  - Fire emissions & daily geo-location
  - 1st use of NOAA's HMS & SMARTFIRE but…
  - Lacks SLT input
  - Alaska not yet included in SMARTFIRE
- **2008 Final** will have state review & input

NOAA's HMS Catalogues Satellite-detected Fires for Use by SMARTFIRE




August - September, 2005
(Courtesy: USFS / Sonoma)
Helicopter-flown burn perimeters
0
12.5
25
50 Kilometers


(Courtesy: USFS / Sonoma)
August - September, 2005
ICS-209 Reports (ignition point)
Helicopter-flown burn perimeters
0
12.5
25
50 Kilometers


MODIS thermal anomalies
ICS-209 Reports (ignition point)
Helicopter-flown burn perimeters
August - September, 2005
(Courtesy: USFS / Sonoma)
0
12.5
25
50 Kilometers

Limitations of Satellites and SMARTFIRE

- Satellites *DO* miss some fires
  - Cloud cover
  - Fires of short duration
  - Understory burns
- Estimating fire size is challenging
  - Sensors not optimal for fires
  - Originally designed for other tasks
  - Uncertainty of conversion of “hot pixels” to acreage

Ground-based Databases are Incomplete & Inconsistent

- Wildfire database for fires > 100 ac
  - Lacks consistency across US
- Prescribed/Ag Burns
  - Paper records (if at all) – very little digital data
  - Permitted burns – often not accomplished, no confirmation
- Other ground-based databases
  - FETS – participation by several western states
  - Handful of other states with digital datasets
  - SE and South Central have greatest need
- Issue with “unclassified” fires
  - Mainly prescribed and agricultural burns (some are
  - Huge issue in SE & South Central

SMARTFIRE Reconciles HMS Satellite-detected Fires with Ground-based Data Systems

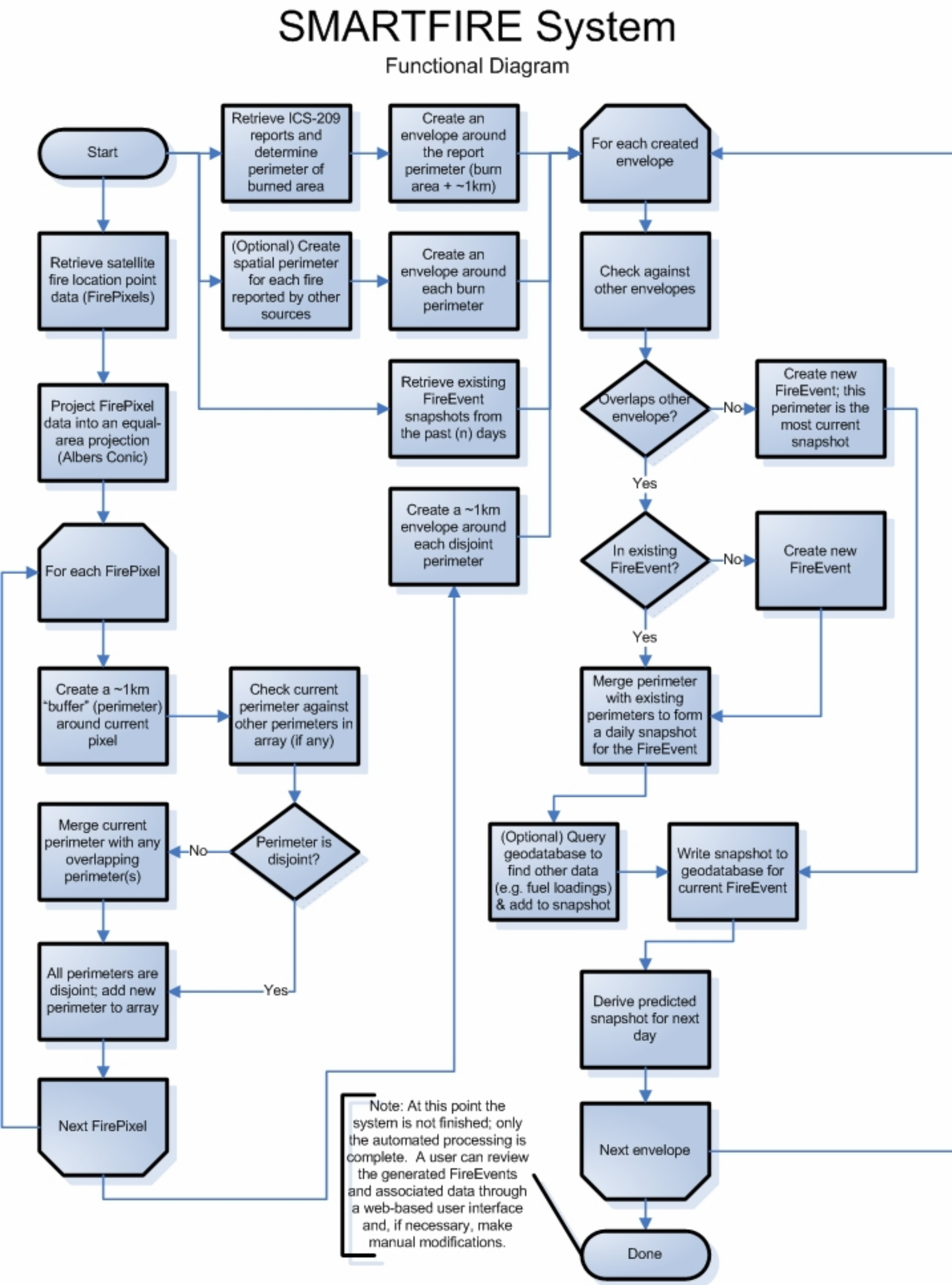
Ground-based systems

Satellite-detected fires (NOAA HMS)

Expert Users
(e.g. Incident Command Teams)

SMARTFIRE

Adapted from AIRFire (Sim Larkin)
http://www.airfire.org/



How SMARTFIRE Works

- SMARTFIRE uses NOAA Hazard Mapping System satellite fire detects along with ground reports from systems such as ICS-209 reports to create a reconciled fire information data feed.
- SMARTFIRE was developed by the USDA Forest Service AirFire Team and Sonoma Technology, Inc. under a grant from NASA.
- SMARTFIRE interfaces with the BlueSky framework to estimate daily, location specific fire emissions

http://www.getbluesky.org/smartfire

SMARTFIRE Reconciles HMS Satellite-detected Fires with Ground-based Data Systems

Ground-based systems

Satellite-detected fires (NOAA HMS)

Expert Users
(e.g. Incident Command Teams)

SMARTFIRE

Reconciled fire info including acreages and locations

BLUESKY

Adapted from AIRFire (Sim Larkin)
http://www.airfire.org/

The (new) BlueSky Framework in Beta Testing to Selected Users

Fire Info

SMARTFIRE
ICS-209
Rx Sys
Manual
Other

Fuels

FCCS
NFDRS
Hardy
LANDFIRE*
Ag*
Other

Total Consumption

CONSUME 3
FOFEM
FEPS
EPM
ClearSky (Ag)*
Satellite*
Other

Time Rate

Rx / WF
FEPS
FOFEM
EPM
WRAP
Idealized
Manual
Other

Emissions

FEPS
Literature*
EPM
FOFEM
Other

Plume Rise

Briggs
Multi-core**
Daysmoke**
Other

Dispersion / Trajectories

CalPuff
HYSPLIT
CMAQ
GEMAQ**

1296 different paths in Beta

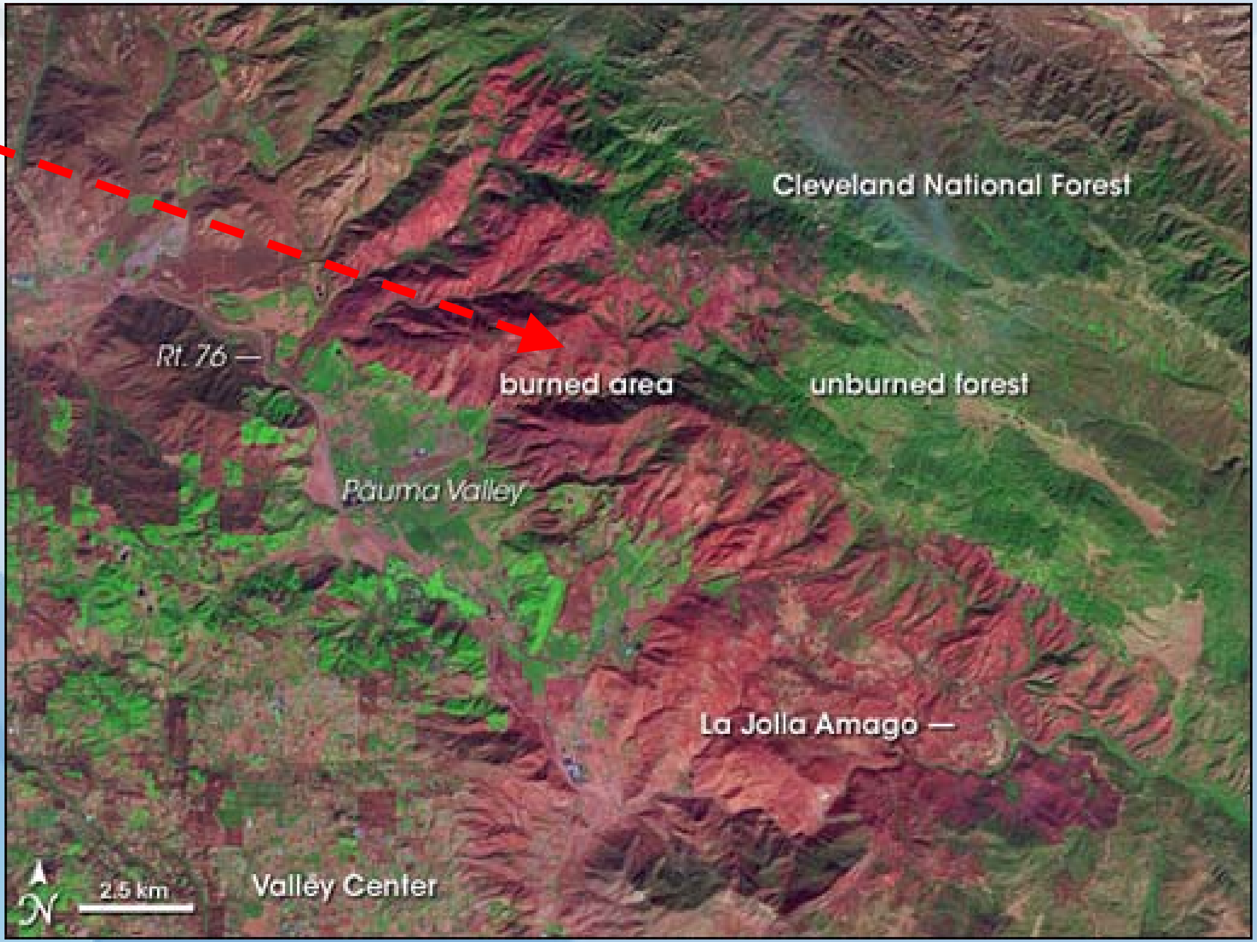
Adapted from S. Larkin
http://www.airfire.org/

Post 2008 Fire EI Development – New Generation of Hybrid Fire EI Methods

- **Fire Emissions Tracking System**
  - FETS in WRAP States – partial participation
  - Other Fire Tracking Systems **(e.g., Florida)**
  - SE & South Central ~ area with biggest need
- **More Refinement & Reliance on SMARTFire**
  - Automated integration of Events databases & Satellite data
- **Ongoing Tools Development & Research**
  - BlueSky Framework Enhancements – 3.0 released
  - Improved fuels databases under development
  - Multi-chimney, plume rise – MISR, Calypso
  - Near real-time emissions modeling in beta (West)
  - Improved use of existing spectra data to estimate fuel consumption
  - Improved area burned data from satellite observations of burn scar

Satellite Data for Burn Scar Assessment

Burn Scar



Source: NASA Terra

Improving the NEI's Fire EI
Evolution of the NEI for Fires

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    - Spatial allocation to counties using forested area
  - Emissions Processor ~ Allocates Diurnal & Monthly
- **2002 –** Fires treated as Point Sources
  - Average daily emissions & 1st-day-of-fire location
  - Expensive "Snapshot" of 2002 – cost not sustainable
- **2003-2008**
  - SMARTFIRE ~ BlueSky (w/state review and input for 2008)
- **2008**
  - 1st use of new NEI EVENTS module

What Information will be Stored in the Events Module?

Component Name	Required/ Optional	Description
Event	Required	Identifies the event, reporting land manager, management methods, and data sources.
Shape File (attach)	Optional	An attached set of geospatial shape files about the event.
Merged Events	Optional	Identifies discrete fires that merged into the current complex fire event.
Event Reporting Period	Required	The time period for which emissions are reported.
Event Location	Required	Identifies the location where the event occurred.
Geographic Coordinates	Required GC or GP	Describes geographic location of event using latitude/longitude coordinates.
Geospatial Parameters	Required GP or GC	Describes geospatial location of event using shape file information.
Event Emissions Process	Required	Identifies the SCC, fuels, fuel conditions, combustion characteristics, and activity that produced emissions.
Emissions	Required	Contains information on all the pollutants being reported for the location, process, and time period (Includes the units of measure, methods, emission factors and emissions as calculated
Attached File	Optional	References an attached file in the schema.

Key Dates for 2008 NEI Events Reporting (DRAFT)

EPA instructs S/L/Ts on providing fire dates & locations data to SMARTFIRE.	*Dec 31, 2008*
Deadline for S/L/Ts to provide fire dates & locations to SMARTFIRE-readable data systems in order for EPA/SMARTFIRE to model emissions for the 2008 NEI.	*Jul 1, 2009*
EPA develops a national fire emissions inventory for the 2008 NEI using SMARTFIRE's satellite- and ground-based reports, includes those furnished by S/L/Ts.	*Jul 1 - Oct 1, 2009*
EPA's national fire emissions inventory is available on the EIS Gateway for S/L/T review.	*Oct 1, 2009*
SLT's submit alternative fire emissions inventory data to the EIS.	*Jul 1, 2009 - Jun 1, 2010*
Stakeholders review and comment on draft NEI.	*Jul 13 - Nov 1, 2010*

Evolution of Fire Emissions Estimation ~Summary~

- Pre 2002 ~ simplified, top-down
- 2002 ~ event-based, extensive “cleanup”
- 2003 - 2008 ~ 1st generation hybrid
  - Satellite / ground data integration
- Future ~ 2nd generation hybrid
  - Expanded events databases
  - Improved algorithms to interpret information from satellites
  - Improved fire perimeter & area burned
    - Post-fire burn scar analysis
    - Improved use of existing sensor spectra
  - Improved plume rise estimates

Questions

Wildfire Smoke – August 2009

JK Brooks85