Temporal and Spatial Detail of On-road Mobile Emission Inventories for Regional Air Quality Modeling

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Outline

• Introduction to emissions processing for motor vehicles
• Denver SIP on-road emissions
• CONCEPT vs. SMOKE-MOVES
• Impacts of processor selection
  – Emissions totals
  – Predicted ozone
Introduction to Emission Processing

• Goal: prepare emissions inventory that is hourly, gridded, and speciated

• Emissions processing options for on-road mobile
  1. Reformat existing emissions
     Mass emissions over an area
  2. Build the inventory inside emission processor
     Emission factor lookups, VMT, meteorology, etc.

• Two publically available emission processors that build on-road inventories
  – CONCEPT Motor Vehicle
  – SMOKE with SMOKE-MOVES Integration Tools
Denver Case Study

• Denver 8-hour ozone SIP
• On-road mobile emissions prepared three ways

1. MOVES Inventory
   • Area source processing
   • All U.S. counties
   • Average weekday/end in each month

2. SMOKE-MOVES
   • Road type and grid cell processing
   • Colorado counties
   • Episode days

3. CONCEPT
   • Link level and grid cell processing
   • DMA/NFR Counties
   • Episode days
Denver Case Study

• **CONCEPT and SMOKE-MOVES**
  Comparison of the Denver Metropolitan Area and North Front Range (DMA/NFR)
  - Input data, processor differences
  - Emission totals
  - Ozone impacts

• **MOVES Inventory** emissions not compared
  - Intended for areas outside Colorado
  - Default MOVES inputs
CONCEPT Motor Vehicle

• **Consolidated Community Emissions Processing Tool**
  – Developed by ENVIRON and Alpine Geophysics
  – Open source and freely available
  – Processes all major emission sources
    ▪ Point Sources
    ▪ Area Sources
    ▪ **On-road Mobile Sources**
    ▪ Non-road Mobile Sources
    ▪ Biogenic Emissions
  – Database management system
  – Integration with GIS/spatial tools
CONCEPT Motor Vehicle

• Interface with Travel Demand Models (TDM)
• Link-level (road segment) traffic volumes by time period (e.g. AM peak)
• Trip starts & ends by Transportation Analysis Zone (TAZ) by time period
• Automated traffic recorder (ATR) monitors under pavement pre-processed into temporal profiles used by CONCEPT
• Hourly, link-level speeds in CONCEPT respond to high-volume congestion, just like the TDM
## CONCEPT vs. SMOKE-MOVES

### CONCEPT Motor Vehicle
- Developed by ENVIRON and Alpine
- VMT **weekday multi-hour time period**
- VMT by **individual links** from travel demand models (TDMs)
- Temporal profiles from **automatic traffic recorders (ATRs)**
- Speeds calculated **hourly by link**
- Parked emissions occur spatially according to **TAZ trip distributions from TDM**

### SMOKE-MOVES Integration
- Developed by UNC and ENVIRON
- VMT **annual average day total**
- VMT **county total by road class and vehicle**
- Temporal profiles included with SMOKE setup are **not local**
- Speeds are **average by road class**
- Parked emissions occur spatially according to gridding surrogates: **75% on roadways and 25% on human population**
CONCEPT vs. SMOKE-MOVES

CONCEPT and SMOKE-MOVES have much in common

- Both use gridded meteorological (MET) data
- Both use MOVES emission factor lookup tables
- In this modeling MOVES inputs, MET files, and chemical speciation were identical

Key differences: local data & calculation methods

1. Temporal profiles
2. Off-network spatial allocation
3. Vehicle speed algorithms
4. MET data processing
Temporal Profiles 1 of 2: *Total VMT*

- Average day total VMT matches well, within 0.4%
- SMOKE temporal profiles miss the AM rush hour that CONCEPT captures
- CONCEPT uses local automated traffic recorder (ATR) continuous counts

Hour (MDT), Thursday to Wednesday, July 10 to 16, 2008
Temporal Profiles 2 of 2: **Fleet Mix**

**CONCEPT**

- Fleet mix varies by hour and day type
- SMOKE fleet mix nearly flat
- Heavy Duty portion of VMT is important due to relatively high NOx emission factors
- Timing of emissions is important

**SMOKE-MOVES**

- CONCEPT fleet mix
- SMOKE fleet mix
- Heavy Duty portion of VMT is important
- Timing of emissions is important
Off-network Spatial Allocation

Trip Starts
- Carbon monoxide emissions
- Start Exhaust
- 9AM, July 14, 2008

Trip Ends
- Paraffin emissions
- Evap. Fuel Vapor Venting
- 3PM, July 14, 2008

CONCEPT estimates off-network emissions in TAZs where trips occur.
Vehicle Speeds

• CONCEPT calculates speeds by link and hour
  – Designed to use TDM’s Bureau of Public Records (BPR) curve
  – Can implement any other speed function

• The BPR curve

\[ S_a = \frac{S_{ff}}{1 + \left( A \times \left( \frac{V}{C} \right)^B \right)} \]

- \( S_a \) = Actual speed (mph)
- \( S_{ff} \) = Free Flow speed (mph)
- \( V \) = Volume of link (vehicles/hour)
- \( C \) = Capacity of link (vehicles/hour)
- \( A, B \) = Empirical constants

• SMOKE-MOVES speeds are input by road class and annual average day or hourly
Diurnal Temperatures

• In MOVES one hydrocarbon emission process depends on previous hours’ temperatures: **Evaporative Fuel Vapor Venting from parked vehicles**
  – Meteorological data → unique temperature profile by grid cell
  – Too calculation-intensive

• Both CONCEPT and SMOKE-MOVES **average** diurnal temperature profiles over geographic areas

• CONCEPT uses episode-day specific profiles per area per day

• SMOKE-MOVES uses an average episode normalized (0,1) diurnal profile, fits the daily min/max to the normalized profile
Compare TOG Emissions

Daily total TOG (tons) for 2008 episode days

SMOKE over predicts overall TOG compared to CONCEPT by 20-50%

- Off-network Evaporative Fuel Vapor Venting:
- Method of estimating these emissions clearly important to TOG daily totals
Compare NOx Emissions

Daily total NOx (tons), 2008 episode days

SMOKE predicts lower NOx compared to CONCEPT by 5-25%

- HD Diesel vehicles contribute more NOx in CONCEPT than SMOKE
  - Weekdays 70-100%
  - Weekends 10-30%

- Causes
  - Slightly larger HDDV mix
  - Slower speeds on weekdays
Smaller differences noted in CO, NH₃ and SO₂ between CONCEPT and SMOKE

- CO differs 1-15%  
  - Larger on weekdays
- NH₃ differs 0-14%
- SO₂ differs 0-4%
Impact on Ozone Formation 1/2

• CAMx model ozone sensitivity:
  What are the impacts in the Denver urban area?
  – CONCEPT Motor Vehicle
  – SMOKE-MOVES
  – MOVES Inventory
  – Zero-out all on-road mobile emissions

• Review highest ozone day (July 10)
  – Nine monitors’ 8-hour ozone averages 81-93 ppb

• Results from each on-road scenario minus the zero-out shows the motor vehicle processing methods’ contributions to ozone
Impacts on Ozone Formation 2/2

• Summary of contributions to 8-hour $O_3$ on July 10, 2008

- 1.5 ppb and 1.3 ppb are significant discrepancies
- CONCEPT vs. SMOKE-MOVES
  - CONCEPT predicted higher ozone at 4 monitors, located northeast of Denver
  - CONCEPT predicted lower ozone at 5 monitors
- Overall motor vehicle contribution to $O_3$ is between 0.5 and 5.5 ppb
Conclusions

• CONCEPT uses more local data and more detailed calculation methods than SMOKE-MOVES

• SMOKE predicts more TOG (20-50%) and less NOx (5 to 25%) than CONCEPT

• On high ozone days this can make a difference of up to 1.5 ppb difference in 8-hour ozone

• Many monitors showed smaller impacts, and results could vary for other cities

• Air quality managers need to consider to what degree local data and detailed calculations should be used
Thanks

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