

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



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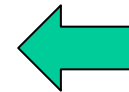
Outline

- 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

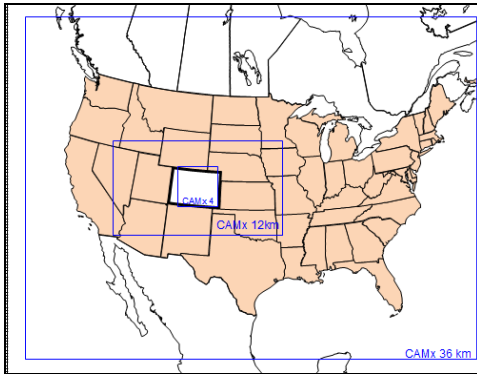


**Superior
Method**

Denver Case Study

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

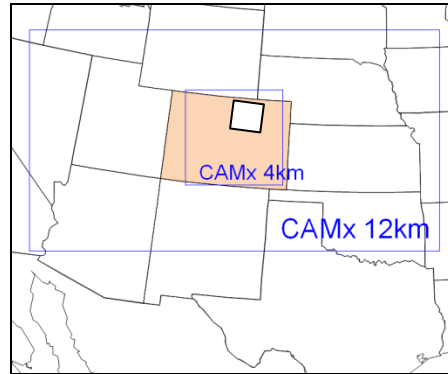
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MOVES Inventory

- Area source processing
- All U.S. counties
- Average weekday/end in each month

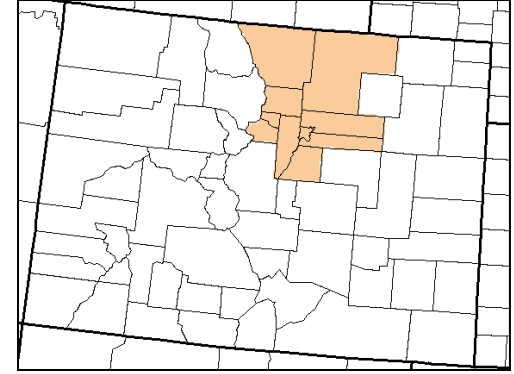
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SMOKE-MOVES

- 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

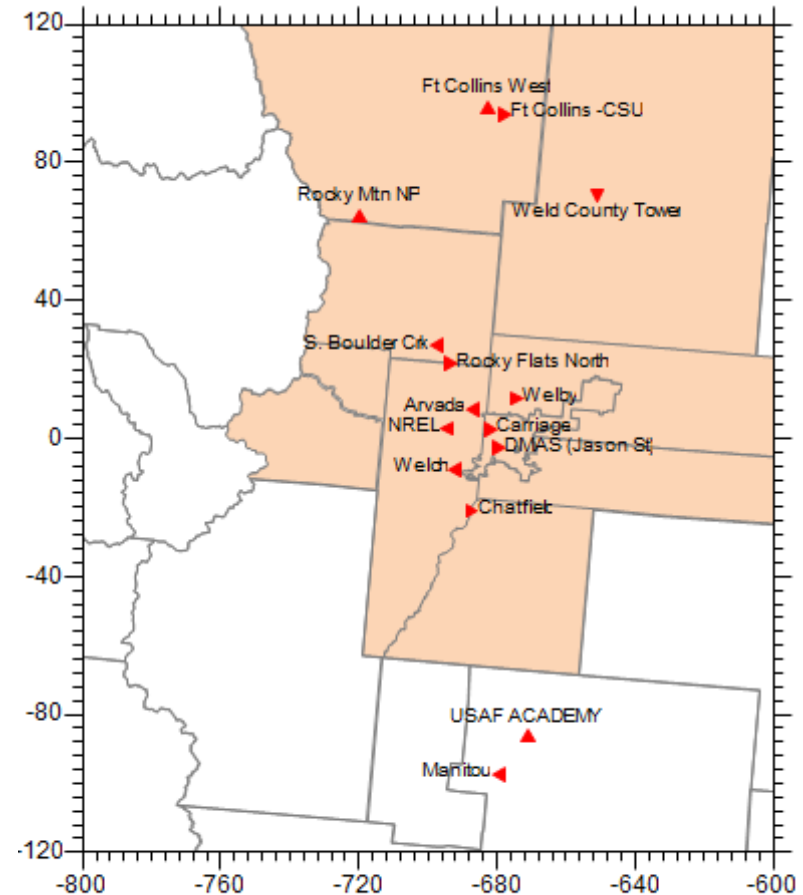
- **CONCEPT and SMOKE-MOVES**

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



2008 AQS Ozone Monitoring Sites near Denver

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

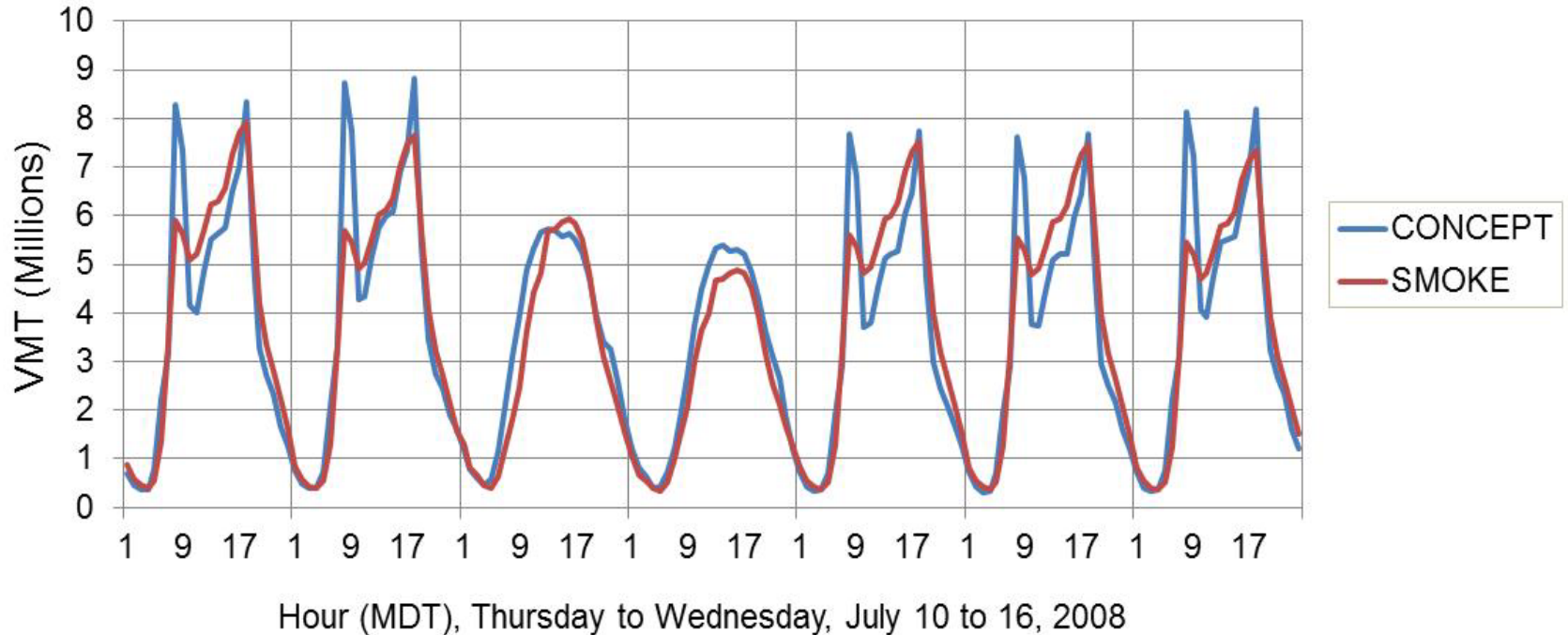
CONCEPT and SMOKE-MOVES have much in common

- 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

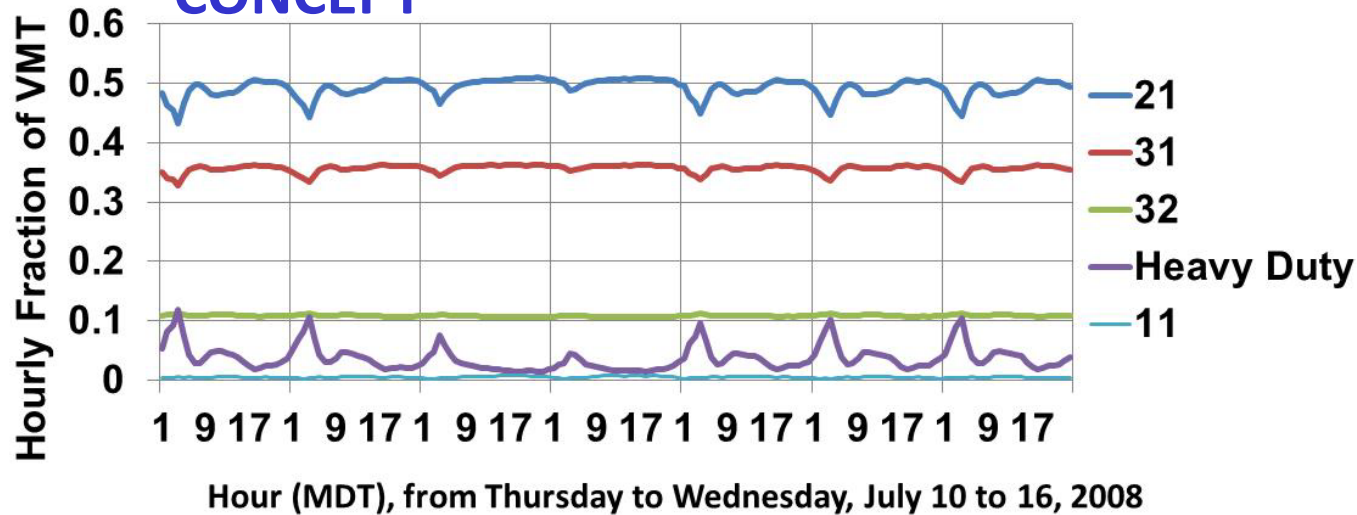
Temporal Profiles 1 of 2: *Total VMT*



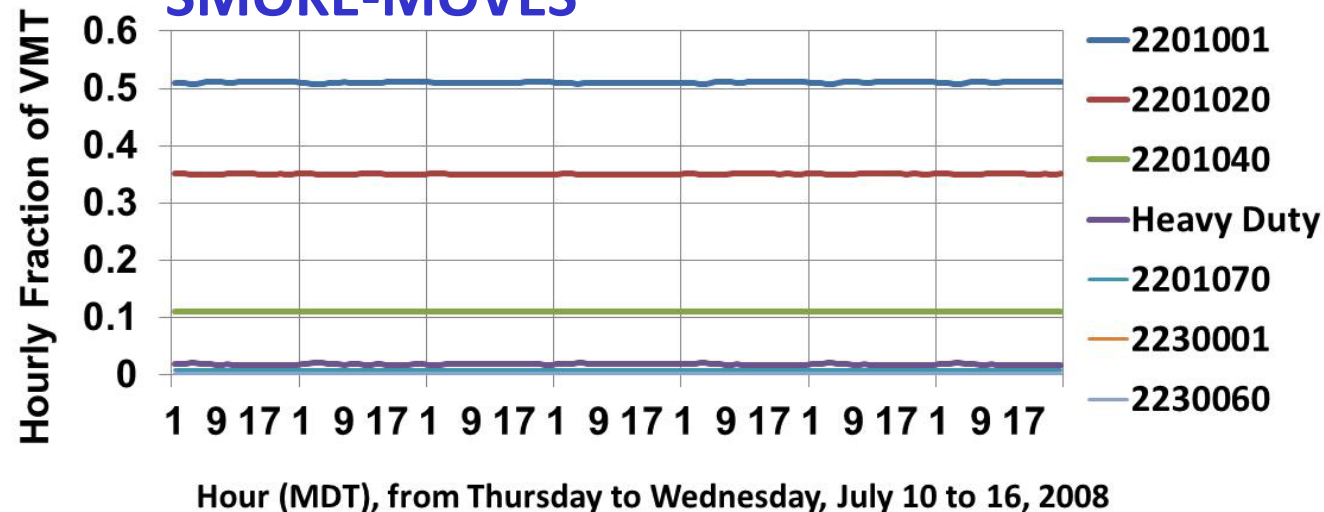
- Average day total VMT matches well, within 0.4%
- SMOKE temporal profiles miss the AM rush hour that CONCEPT captures
- CONCEPT uses local automated traffic recorder (ATR) continuous counts

Temporal Profiles 2 of 2: *Fleet Mix*

CONCEPT



SMOKE-MOVES



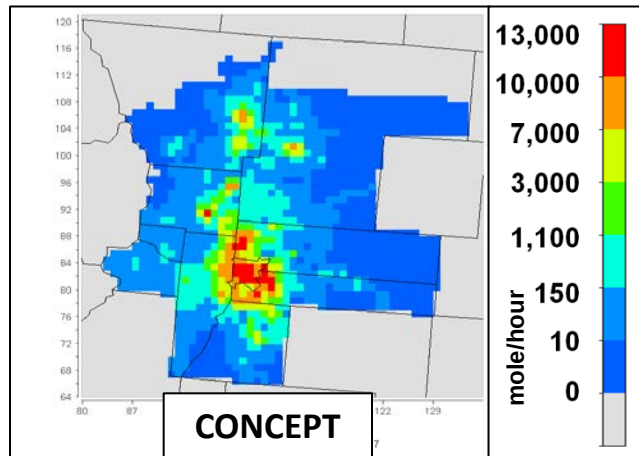
Fleet Mix = vehicle type contribution to VMT

- 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 NO_x emission factors
- Timing of emissions is important

Off-network Spatial Allocation

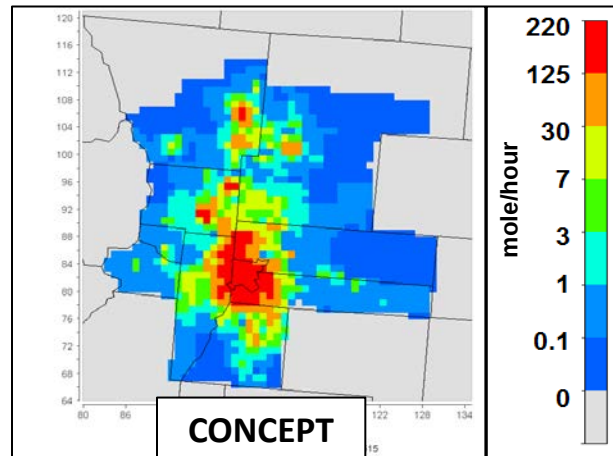
Trip Starts

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

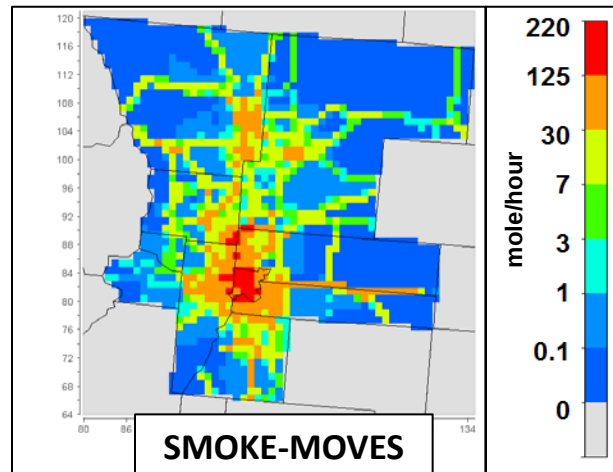
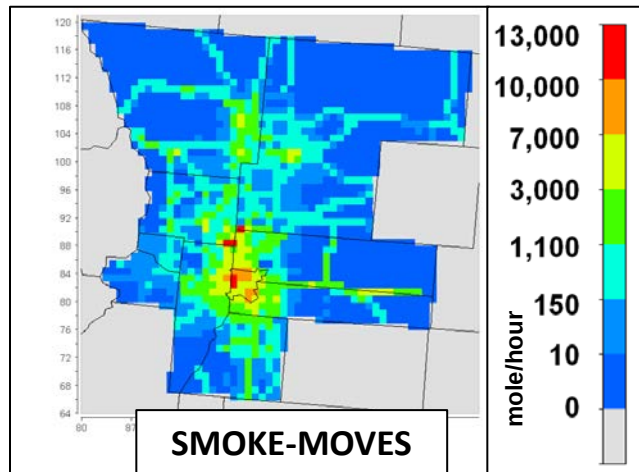


Trip Ends

- 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

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

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

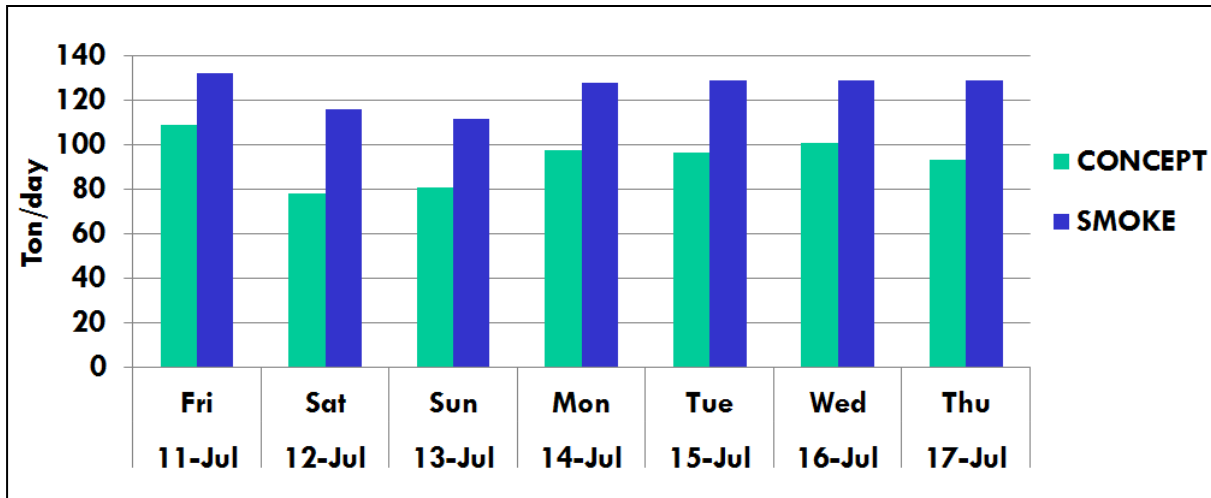
- SMOKE-MOVES speeds are input by road class and annual average day or hourly

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

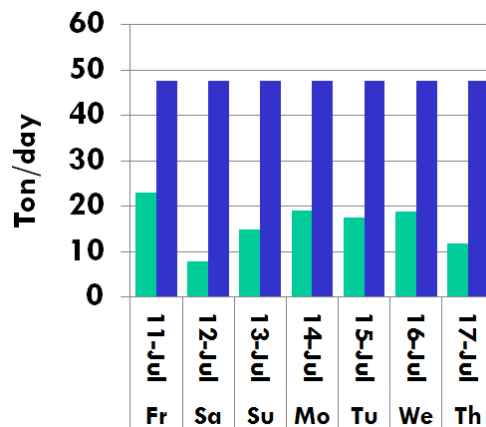
Compare TOG Emissions

Daily total TOG (tons) for 2008 episode days

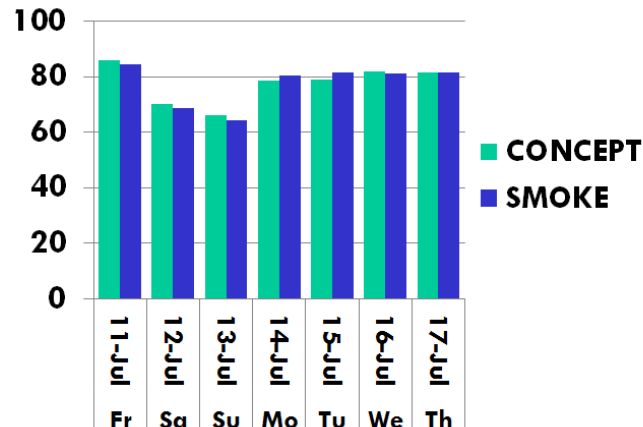


SMOKE over predicts overall TOG compared to CONCEPT by 20-50%

Off-network Evaporative Fuel Vapor Venting:



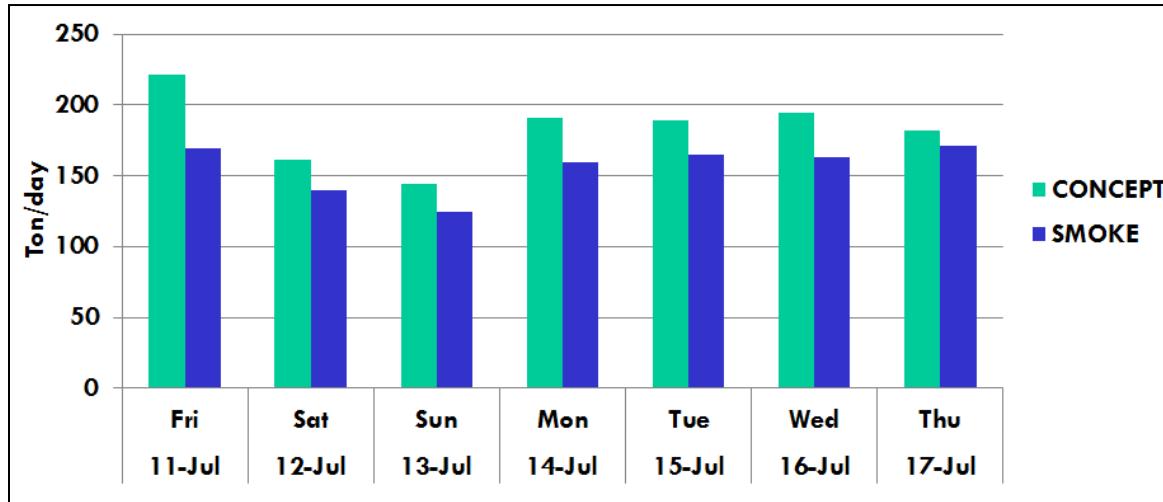
All other TOG:



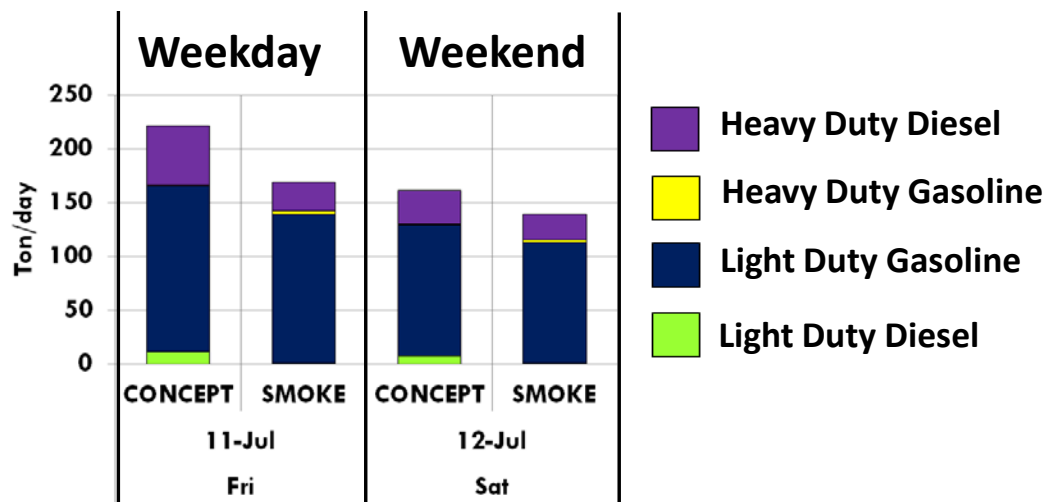
- Off-network Evaporative Fuel Vapor Venting from SMOKE >> CONCEPT
- Method of estimating these emissions clearly important to TOG daily totals

Compare NOx Emissions

Daily total NOx (tons), 2008 episode days



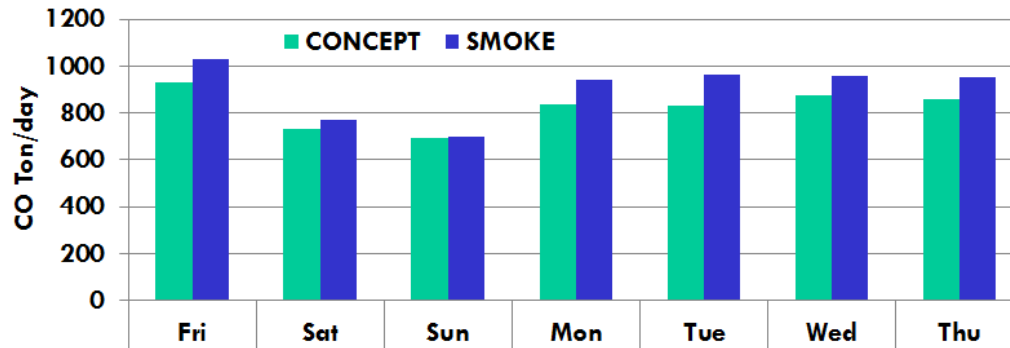
SMOKE predicts lower NOx compared to CONCEPT by 5-25%



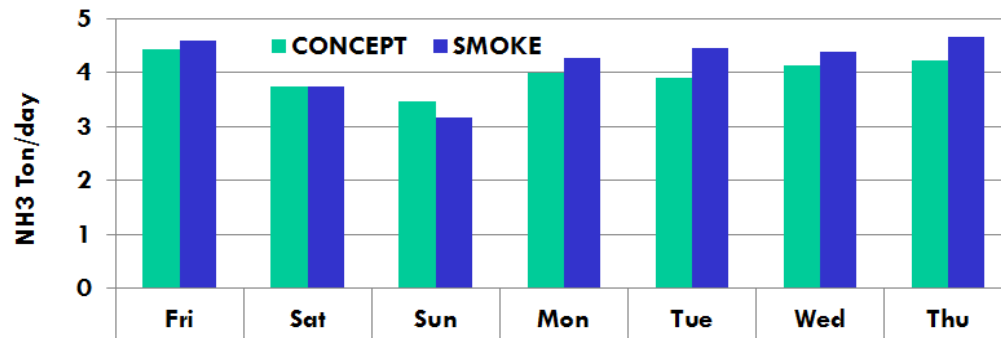
- HD Diesel vehicles contribute more NOx in CONCEPT than SMOKE
 - Weekdays 70-100%
 - Weekends 10-30%
- Causes
 - Slightly larger HDDV mix
 - Slower speeds on weekdays

Compare other Pollutants' Emissions

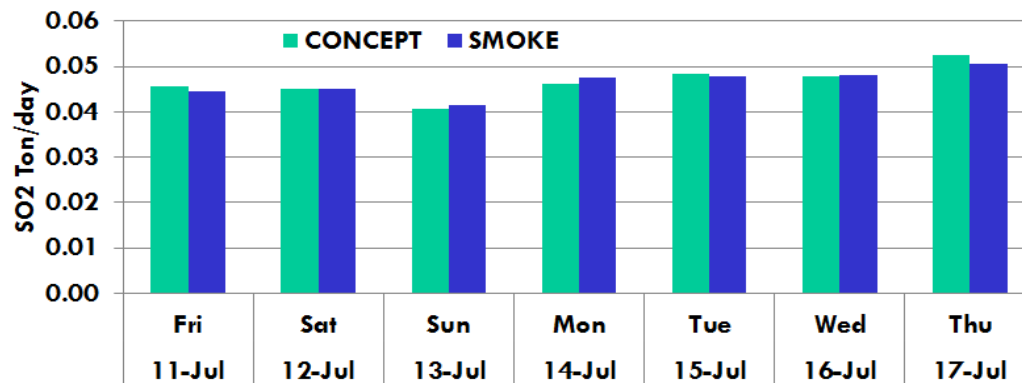
CO



NH₃



SO₂



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

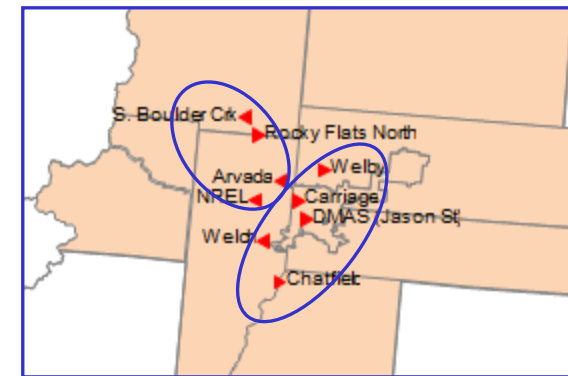
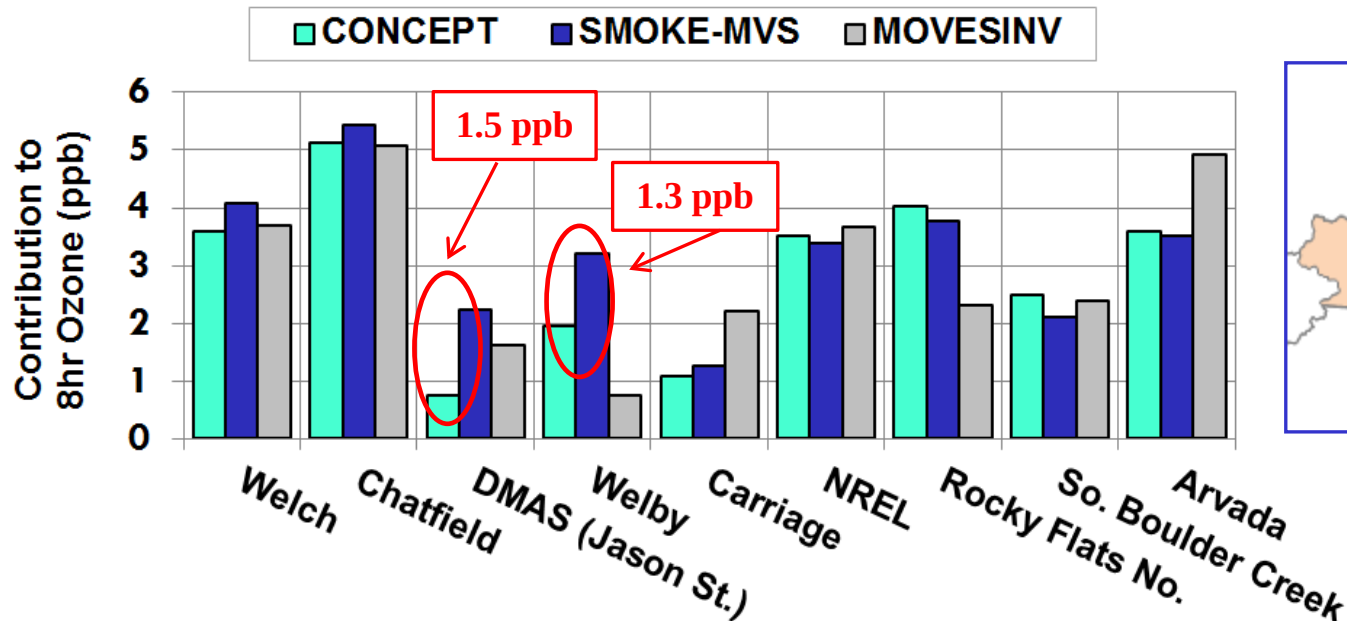
- CAMx model ozone sensitivity:

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 O₃ on July 10, 2008



- 1.5 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 O₃ 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

- Alpine Geophysics, LLC
- Denver Regional Air Quality Council
- Colorado Department of Public Health and the Environment
- Denver Regional Council of Governments
- North Front Range Metropolitan Planning Organization