MOVES Sensitivity Analysis:
The Impacts of Temperature and Humidity on Emissions

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What is MOVES?

- MOtor Vehicle Emission Simulator
- Replaces MOBILE for on-road vehicle emissions
  - fundamental redesign
  - extensive updates to model inputs
- Estimates national, state, and county level inventories of:
  - criteria pollutants
  - greenhouse gas
  - air toxics
  - energy consumption
- Approved for use in State Implementation Plan (SIP) and regional conformity analysis
MOVES model

- Facilitates estimation of emissions under user-defined conditions
  - by replacing national defaults with local inputs
  - through County-Data Manager (CDM)

- **MOVES input parameters:**
  - Meteorology – temperature and humidity
  - Vehicle population
  - Age distributions
  - Vehicle miles travelled (VMT)
  - Average speed distributions
  - Road type distributions
  - Ramp fractions
  - Fuel supply
  - I/M program parameters
Meteorology data

- MOVES’ default meteorology database
  - hourly temperature and humidity
  - every county in the country
  - 30 year averages from the National Climatic Data
- Affect estimates of emissions via
  - temperature adjustment
  - humidity correction factor for NOx
  - air conditioning adjustment – function of temperature, humidity
- For SIP and regional conformity analysis, use of local meteorology data encouraged
- Thus, understanding the degree to which temperature and humidity affect emissions results is crucial
MOVES run

- MOVES2010a
- “National” scale
- Gasoline and diesel
- All vehicle types, all road types
- Pollutants
  - Hydrocarbons (HC)
  - Carbon monoxide (CO)
  - Oxides of nitrogen (NOx)
  - Total particulate matter (PM$_{2.5}$)
- Emissions processes
  - CO, NOx, and PM2.5: cold starts and running
  - HC: cold starts, running, and evaporative
Methods

- **Humidity**
  - MOVES default relative humidity
  - from 11.5 to 95.3 percent
  - Analysis
    - from 0 to 100 percent in increments of 10
    - at a given temperature between 25 to 100 F

- **Temperature**
  - MOVES default temperature
    - from -24.5 to 107.5 F
  - Analysis
    - from -40 to 120 F in increments of 10 degrees
  - the relationship between temperature and humidity examined to isolate the effect of temperature
Temperature vs. Relative Humidity

The graph shows a scatter plot with Temperature (F) on the x-axis and Relative Humidity (%) on the y-axis. The data points are distributed across the range of temperatures and humidities, indicating a relationship between the two variables.
Temperature vs. Specific Humidity

\[ y = 4.321e^{0.0383x} \]
\[ R^2 = 0.9601 \]
Results

- Aggregate emission estimates of all vehicle types, processes, and road types
- Percent change in emissions in relation to incremental changes in temperature and humidity
- Base temperature: 75 F
- Base humidity: zero percent
Temperature - Gasoline

NOx

Emissions (% change)

Temperature (F)

Starts

Running

CY 2005
CY 2015
CY 2020
Temperature - Gasoline

![Graph showing emissions vs temperature for CO over different years (CY 2005, CY 2015, CY 2020).](image)

- Starts
- Running
Temperature - Gasoline

![Graph showing THC emissions (% change) vs. Temperature (°F) over different years (CY 2005, CY 2015, CY 2020). The graph indicates a decrease in emissions with increasing temperature. Symbols for Starts and Running & Evap are shown.]
Temperature - Gasoline

![Graph showing Total PM$_{2.5}$ emissions vs. temperature (F) with lines for CY 2005, CY 2015, and CY 2020. The graph indicates a downward trend with temperature, no significant temperature effect on emissions.]

Running & Starts: No temperature effect
Temperature - Diesel

CO

- Emissions (% change)
- Temperature (F)

CY 2005, CY 2015, CY 2020
Temperature - Diesel

THC

Emissions (% change)

Temperature (F)

CY 2005
CY 2015
CY 2020
Temperature - Diesel

![Graph showing NOx emissions vs temperature for CY 2005, CY 2015, and CY 2020. The emissions decrease as temperature increases.]
Temperature - Diesel

![Graph showing Total PM$_{2.5}$ emissions vs temperature for different years (CY 2005, CY 2015, CY 2020). The graph indicates a slight increase in emissions with decreasing temperature.](image-url)
Humidity - Gasoline

CO

Emissions (% change) vs. Relative Humidity (%)

- 75%
- 80%
- 85%
- 90%
- 95%
- 100%
Humidity - Gasoline

THC

Emissions (% change)

Relative Humidity (%)
Humidity - Gasoline

![Graph showing NOx emissions as a function of Relative Humidity for different gasoline grades.](image)
Humidity - Gasoline

Total PM$_{2.5}$

Emissions (% change)

Relative Humidity (%)
Humidity - Diesel
Humidity - Diesel

THC

Emissions (% change)

Relative Humidity (%)
Humidity - Diesel

![Graph showing the relationship between Relative Humidity (%) and Emissions (% change) for different NOx levels. Each line represents a different NOx level, with lines for 25, 35, 45, 55, 65, 70, 75, 80, 85, 90, 95, and 100. The graph demonstrates that as Relative Humidity increases, emissions decrease.]
Humidity - Diesel

Total PM$_{2.5}$

Relative Humidity (%) vs. Emissions (% change)

- 70
- 80
- 85
- 90
- 95
- 100
Summary

- **Temperature**
  - substantial impact on MOVES’ estimates of emissions
    - especially for cold temperatures
  - by fuel type
    - magnitude of impact greater for gasoline vehicles than diesel
      - gasoline
        - PM2.5: most sensitive
        - HC and CO: highly sensitive
      - diesel
        - HC: most sensitive
        - PM2.5: not sensitive
  - by calendar year
    - as vehicles get cleaner, sensitivity to temperature increases
Summary (cont’d)

- **Humidity**
  - by pollutant
    - HC and CO
      - sensitive for temperatures above 75 F
    - NOx
      - sensitive for temperatures above 25 F
      - exhibit increased sensitivity with increasing humidity
    - PM2.5
      - Not responsive to changes in humidity for both gasoline and diesel
  - by fuel type
    - gasoline vehicles more sensitive than diesel
  - by calendar year
    - sensitivity does not vary (within 1 percent)
Conclusion

- Emissions inventories can be estimated more accurately using MOVES if the impacts of temperature and humidity on emissions are considered.
- Results emphasize the importance of obtaining accurate local meteorological data.
- Provided assurance for MOVES’ ability to generate reasonable estimates for temperature and humidity beyond MOVES default ranges.
- Future sensitivity analysis:
  - average speed distribution, age distribution, road type distribution, ramp fraction, fuel supply, and I/M program.
References


Thank You Very Much !!!