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

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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

![Graph showing the relationship between Temperature (F) and Relative Humidity (%). The x-axis represents Temperature ranging from -20 to 110 degrees Fahrenheit, while the y-axis represents Relative Humidity ranging from 20 to 100%. The data points are plotted as diamonds, indicating a scatter plot.]
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

![Graph showing the relationship between temperature and NOx emissions for different years (CY 2005, CY 2015, CY 2020). The graph indicates that NOx emissions decrease as the temperature increases, reaching a minimum around 40-50°F, and then increase as the temperature further increases. The graph highlights the transition from 'Starts' to 'Running' conditions.]
Temperature - Gasoline

CO

Emissions (% change)

Temperature (F)

Starts → Running

-40 -30 -20 -10 0 10 20 30 40 50 60 70 80 90 100 110 120

CY 2005 CY 2015 CY 2020
Temperature - Gasoline

THC

Emissions (% change)

Temperature (F)

Starts  Running & Evap
Temperature - Gasoline

Total PM\textsubscript{2.5}

- CY 2005
- CY 2015
- CY 2020

Emissions (% change) vs. Temperature (F)

Running & Starts: No temperature effect
Temperature - Diesel

CO

Emissions (% change)

Temperature (F)

-40 -30 -20 -10 0 10 20 30 40 50 60 70 80 90 100 110 120

CY 2005
CY 2015
CY 2020
Temperature - Diesel

THC

Emissions (% change)

Temperature (F)

CY 2005
CY 2015
CY 2020
Temperature - Diesel

![Diagram showing the relationship between NOx emissions and temperature for different years (CY 2005, CY 2015, CY 2020). The emissions decrease as temperature increases.]
Temperature - Diesel

Total PM$_{2.5}$

- CY 2005
- CY 2015
- CY 2020
Humidity - Gasoline

![Graph showing CO emissions vs. relative humidity]

- Emissions (% change) on the y-axis.
- Relative Humidity (%) on the x-axis.
- Lines represent different humidity percentages:
  - 75%
  - 80%
  - 85%
  - 90%
  - 95%
  - 100%

Graph indicates a positive correlation between CO emissions and relative humidity.
Humidity - Gasoline
Humidity - Gasoline
Humidity - Gasoline

Total PM$_{2.5}$

- Emissions (% change)
- Relative Humidity (%)
Humidity - Diesel

![Graph showing CO emissions (% change) vs. Relative Humidity (%) for different humidities (75, 80, 85, 90, 95, 100).]
Humidity - Diesel
Humidity - Diesel

![Graph showing the relationship between relative humidity and NOx emissions for diesel engines.]
Humidity - Diesel

![Graph showing Total PM<sub>2.5</sub> emissions (% change) vs. Relative Humidity (%) for different fuel percentages.]{24}
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 if the impacts of temperature and humidity on emissions are considered.

- Results emphasize the importance of obtaining accurate local meteorological data.
References

