Development and Application of a Micro scale Emission Factor Model (MicroFac) for Mobile Source Emissions

Rakesh Singh and James Sloan

14th International Emission Inventory Conference
"Transforming Emission Inventories - Meeting Future Challenges Today"
Las Vegas, Nevada
April 11-14, 2005

Waterloo Centre for Atmospheric Sciences

University of Waterloo

Why MicroFac?

- Current emission models such as the *MOBILE* family only deal with time-averaged regional-scale emissions
- They lack:
  - Real-time description
  - Site specificity
- MicroFac has these capabilities and many more

MOBILE Models

- Historically, MOBILE6/5 has been used for vehicle emissions modelling in Canada.
- *MOBILE* is
  - Designed for county-scale (minimum), not street-scale, emission estimates
  - Not designed for
    - ✓ microscale modeling
    - ✓ application in air quality modeling
    - ✓ human exposure modelling

MicroFac Modelling

- The MicroFac algorithm gives emissions in terms of the specific vehicle fleet being considered
- The composite emission for a specified fleet is built up from the contributions of the individual vehicles as follows

$$CEF = \sum_{ij} ER_{ij} * VEH_{ij}$$

Where:

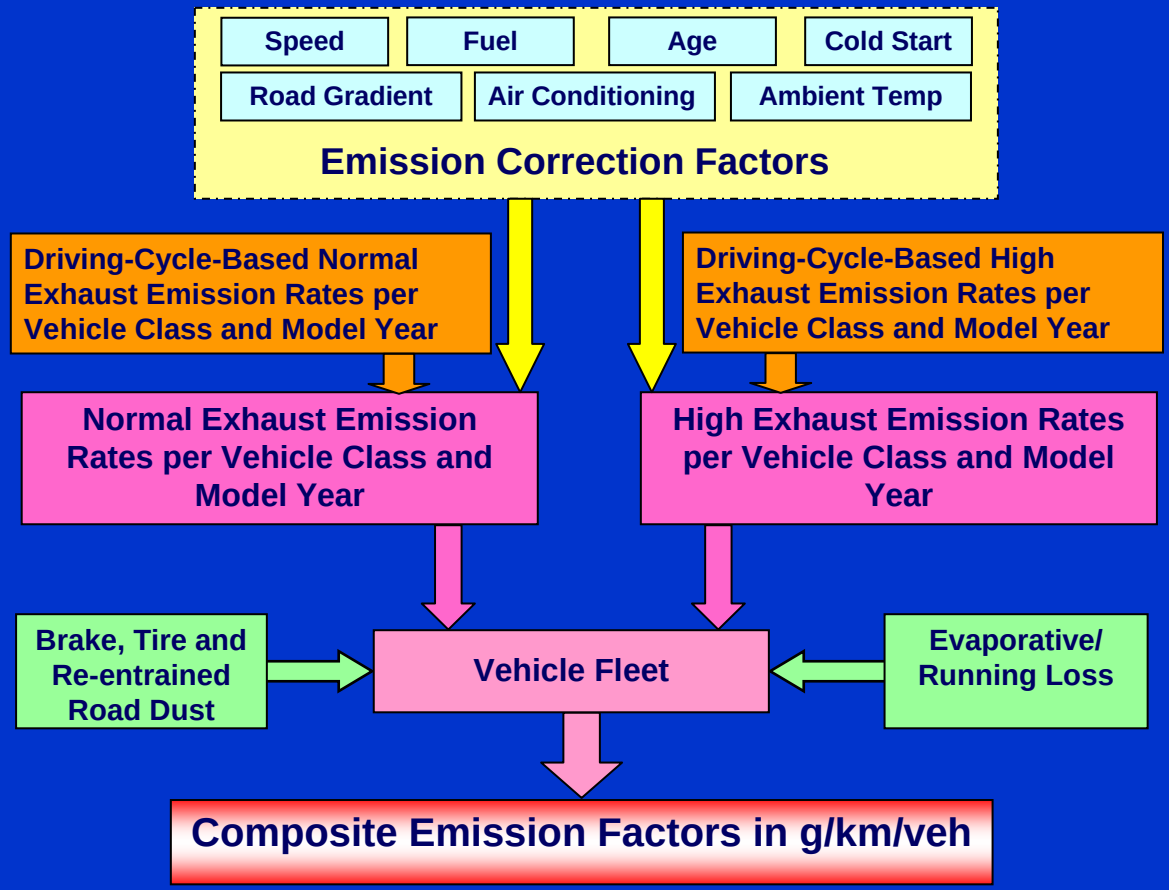
CEF = composite emission factor for the fleet

$ER_{i,j}$ = composite emission factor for vehicle type i and model year j

$VEH_{i,j}$ = fraction of vehicles in the fleet for vehicle type i and model year j

MicroFac Process Flow Diagram

- MicroFac output takes account of the characteristics of the individual vehicles in the fleet as shown below



MicroFac Input Requirements

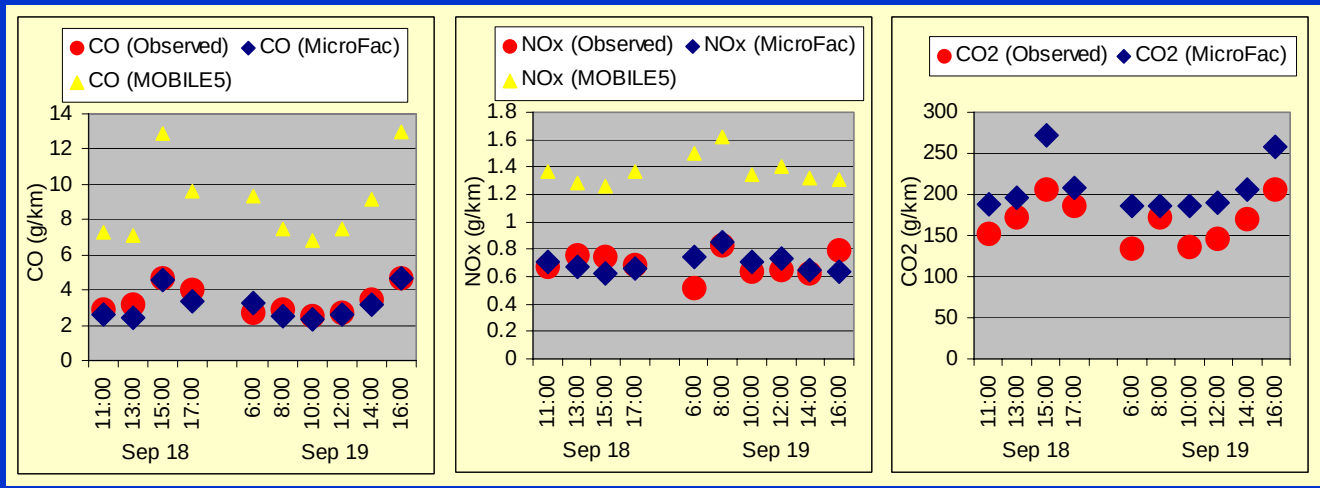
- Date and time
- Ambient temperature and relative humidity
- Average vehicle speed
- Road gradient
- Fuel composition
- Vehicle fleet characterization

MicroFac Evaluation

- Tunnel studies
  - for CO, NOx and CO_2
    - ✓ Callahan Tunnel, Boston 1995
    - ✓ Lincoln Tunnel, New York 1995
    - ✓ Deck Park Tunnel, Phoenix 1995
  - For PM_{10} and $PM_{2.5}$
    - ✓ Tuscarora Tunnel, PA 1999
- Speed, traffic fleet and age distribution were known

Performance of MicroFac (Boston)

- Average Speed= 26.4 (14.1-35.3) mph
- Average Ambient Temperature= 62.1 (50.0-69.1)°F

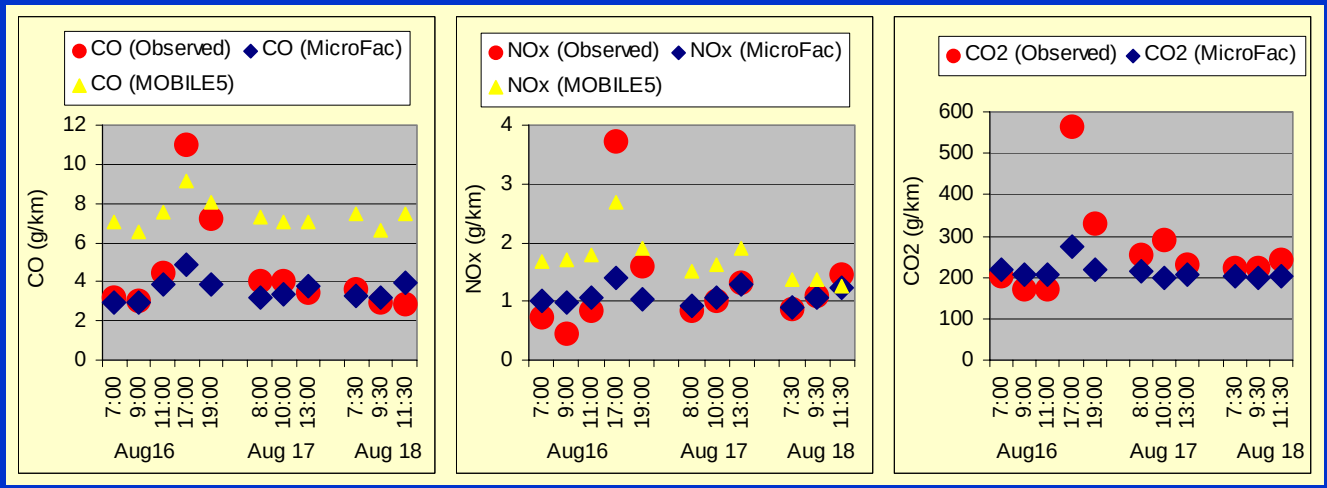


Waterloo Centre for Atmospheric Sciences

University of Waterloo

Performance of MicroFac (New York)

- Average Speed= 27.1 (20.4-30.0) mph
- Average Ambient Temperature= 84.6 (79.5-91.0)°F

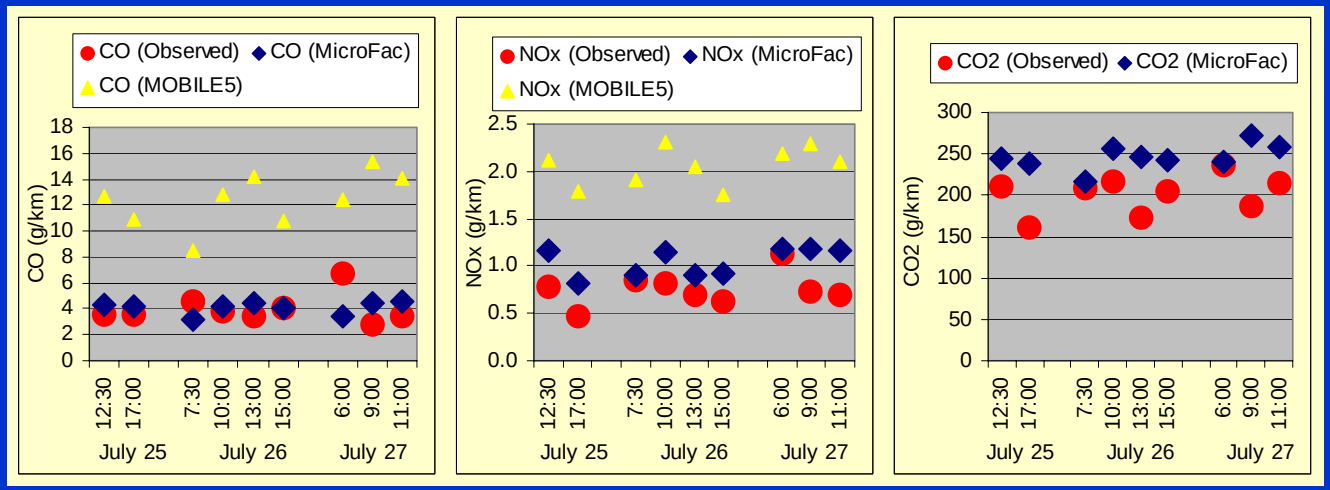


Waterloo Centre for Atmospheric Sciences

University of Waterloo

Performance of MicroFac
(Phoenix)

- Average Speed= 59.7 (58.0-61.9) mph
- Average Ambient Temperature= 103.2 (84.9-110.8) °F

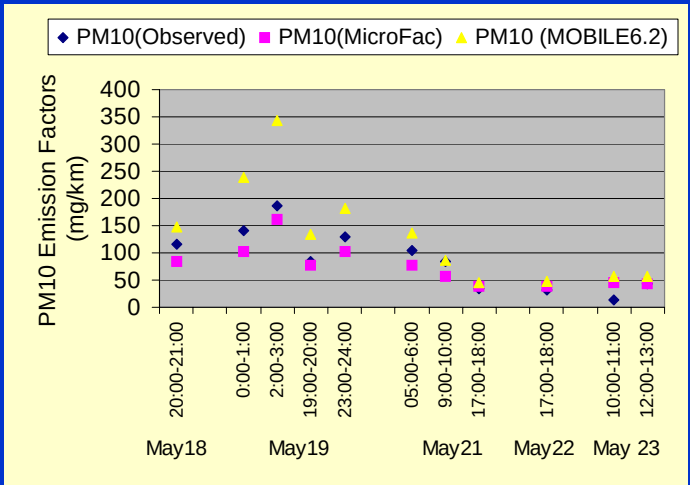


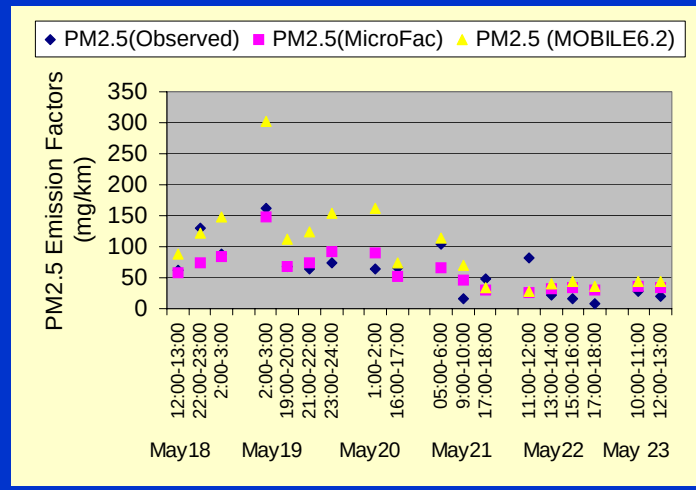
Waterloo Centre for Atmospheric Sciences

University of Waterloo

Performance of MicroFac
(Pennsylvania)

- Average Speed= 56.8 (53.6-61.7) mph
- Light-duty percentage = 56.5 (13.68-88.61) %





Waterloo Centre for Atmospheric Sciences

University of Waterloo

Application in Air Quality Modeling

Micrometeorology

+

On-Road Traffic

↓

MicroFac

↓

Dispersion Model

Site-Specific meteorology

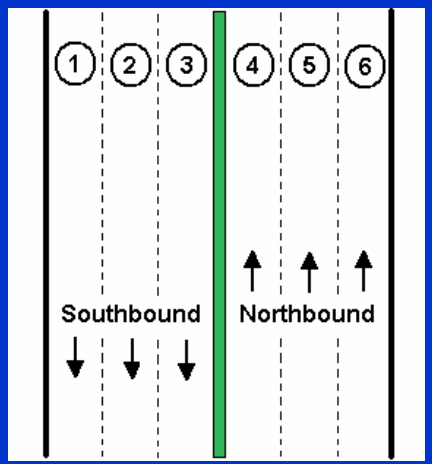
Site-Specific Real-Time Emission Factor Model

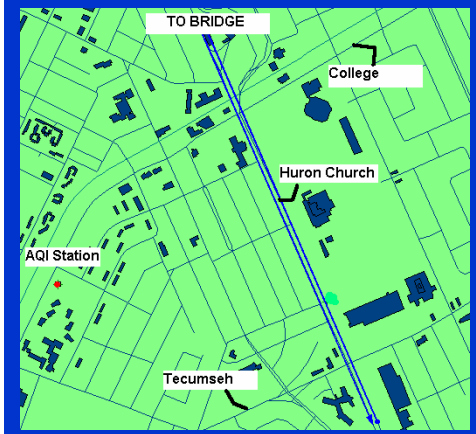
Such as CALINE4 or AERMOD

Waterloo Centre for Atmospheric Sciences

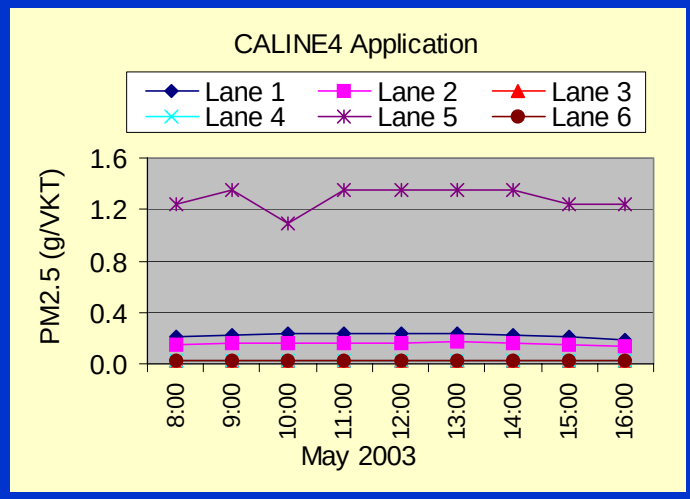
University of Waterloo

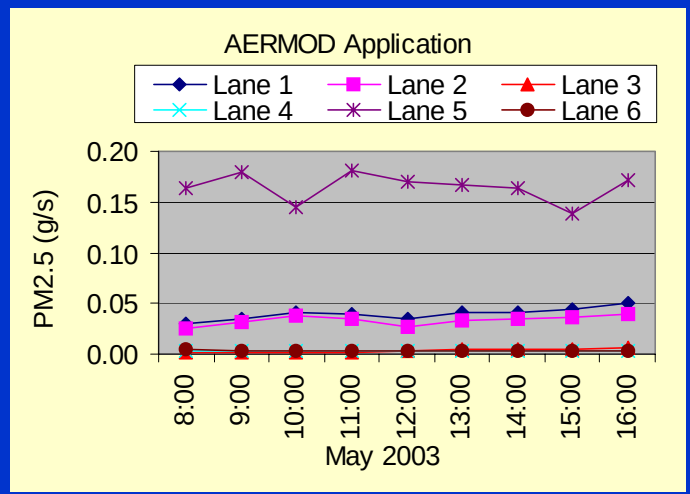
Application of MicroFac (Windsor, ON)





1, 2 Normal traffic + Trucks: Free flow
3, 4, 6. Normal traffic: Free flow
5. Trucks only: Queued



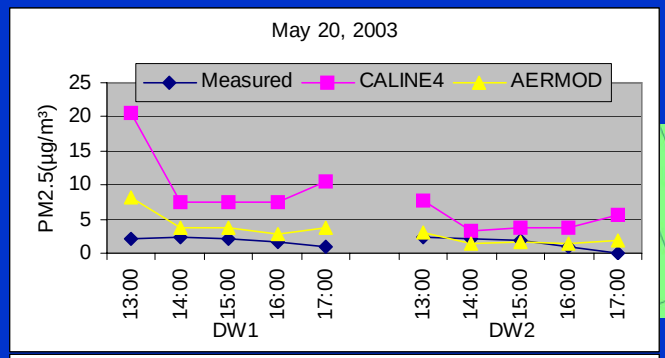


Waterloo Centre for Atmospheric Sciences

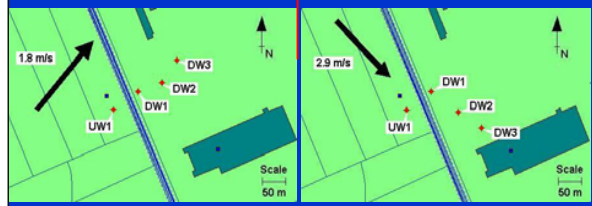
University of Waterloo

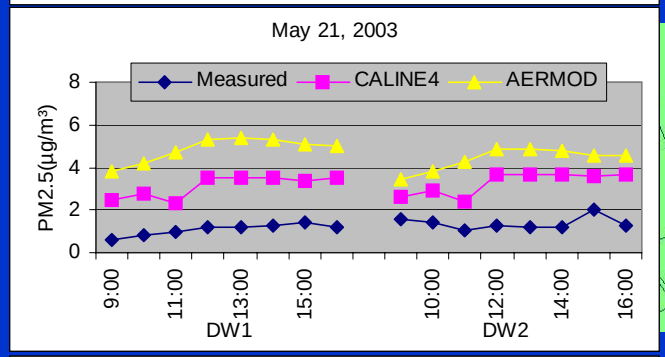
MicroFac + CALINE4/AERMOD
(Windsor, ON)

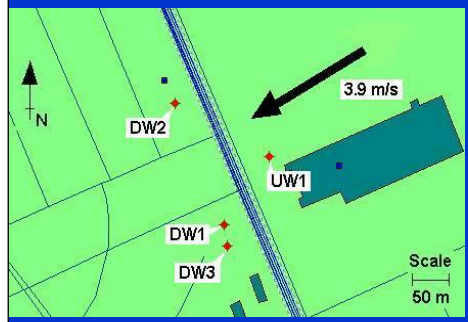
- Monitoring limitations
- No road dust

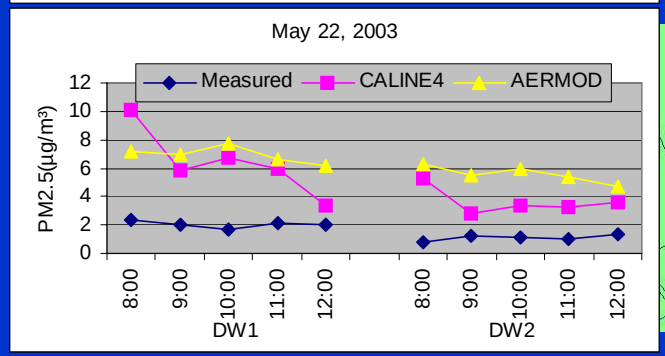


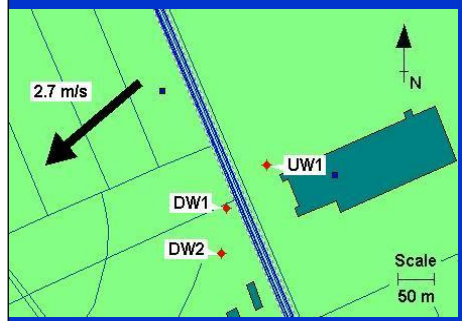
Relocation of the monitoring instruments between 14:00 and 15:00











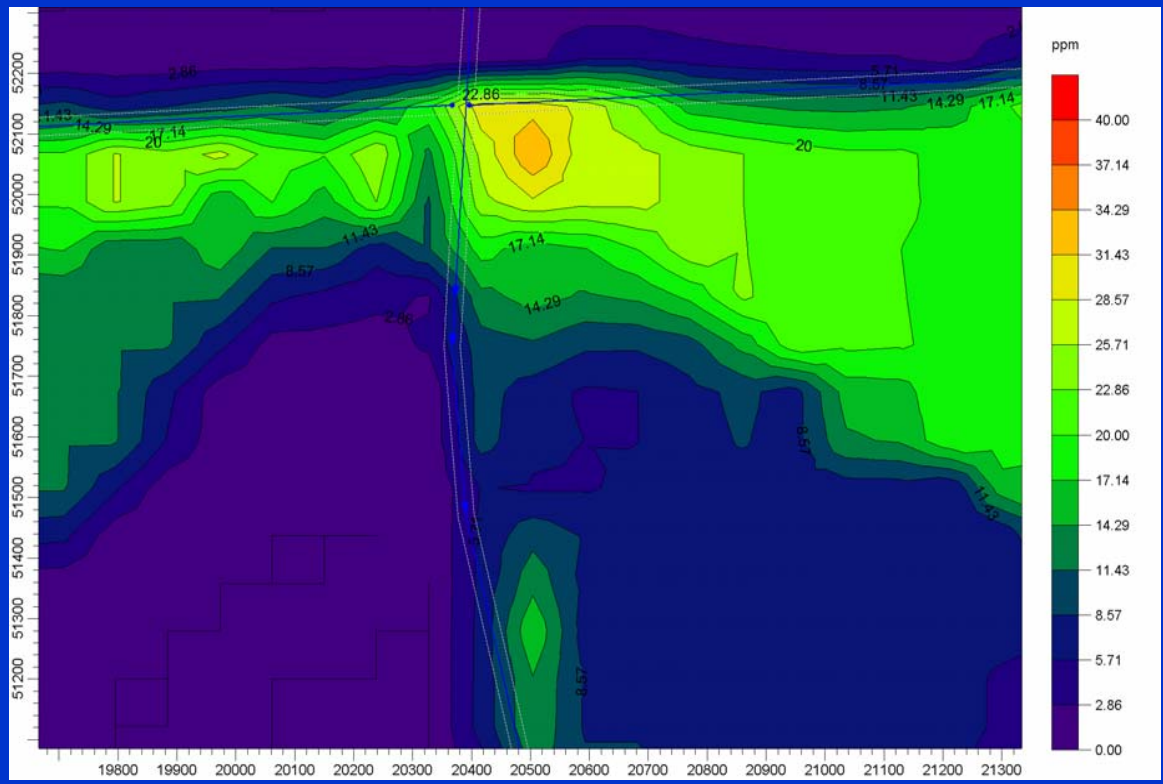
Waterloo Centre for Atmospheric Sciences

University of Waterloo

MicroFac + CALINE4
(Waterloo Region, ON)

July 15, 2002, 11:00; Wind Direction 275º; Wind Speed 2.1 m/s

Cambridge – Hespeler Road



Waterloo Centre for Atmospheric Sciences

University of Waterloo

Application in Remote Sensing

- Remote sensing devices (RSD)
  - Concentrations of material emitted by vehicles in ppm
  - Can be converted to emissions in g pollutant (CO, NOx, HC) / kg fuel used
  - Assumed fuel economy rate is used to convert to emission factors
  - Suitable only for inventory and qualitative assessment
- MicroFac fuel consumption model convert RSD concentrations to emission factors g/km at any speed and driving conditions
  - RSD data analysis and conversion to emission factors for individual vehicles and vehicle fleet

Conclusions

- Site-specific real-time emissions are critical for modeling air transport/dispersion and human exposure in various roadway microenvironments
- MicroFac models for
  - CO and NO_x
  - PM_{10} and $PM_{2.5}$
  - Fuel consumption model
    - ✓ CO_2 model
    - ✓ Remote sensing applications

Acknowledgements

- Funding Agencies
  - NSERC
  - Ontario Power Generation
  - Ontario Ministry of the Environment
  - Ontario Research and Development Challenge Fund

We are grateful for the support of Dr. Alan Huber, NERL, US EPA in the initial MicroFac development and Dr. Alan Gertler, DRI for Tunnels data.