Road source model intercomparison study using new and existing datasets

Jenny Stocker, David Heist, Christina Hood, Vlad Isakov, David Carruthers, Steven Perry, Michelle Snyder, Akula Venkatram, Sarav Arunachalam

Cambridge Environmental Research Consultants, US Environmental Protection Agency Office of Research and Development, University of California at Riverside, University of North Carolina Institute for the Environment

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Motivation

- Pollution issues:
  - Public health concerns related to population exposure to traffic-generated pollutants.
  - Elevated health risks for near-road populations: residential, workplace and schools.
  - Policy makers ask: how will new traffic schemes affect pollution levels?
  - Governments ask: what is the cost of bad air quality?
- What is required:
  - Population exposure calculations require detailed spatial and temporal data.
  - Monitoring can give accurate temporal data but does not have sufficient spatial resolution.
  - Models can perform calculations to the required temporal and spatial resolution – but how accurate are they?

If pollution issues are to be investigated using road source air dispersion models, intercomparison exercises are required to assess the accuracy of the different models available

Motivation

CERC is involved in the cooperation agreement between the UK Environment Agency and the US Environmental Protection Agency (EPA)

"Evaluation of roadway models"

- Comparisons of modelling results with physical experiments
- Comparisons of modelling results from different models
- Focus on near-road concentration distributions

Forthcoming publication:

Heist, D., Isakov, V., Perry, S., Snyder, M., Venkatram, A., Hood, C., Stocker, J., Carruthers, D. and Arunachalam, S., 2013: Estimating near-road pollutant dispersion: a model inter-comparison.

Motivation

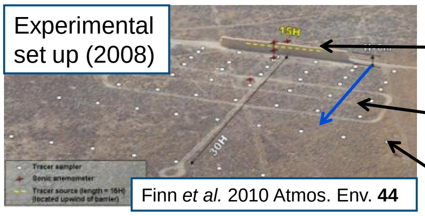
- Field experiments with tracer gas emissions allow focus on modelling dispersion from line sources by reducing uncertainty, for instance:
  - no chemistry
  - little or no buoyancy
  - no background concentrations
  - well-defined emission rates
  - detailed met measurements
  - high density of concentration monitors
- Complementary to modelling of urban areas and comparison with routine monitoring (e.g. EMEP sites)

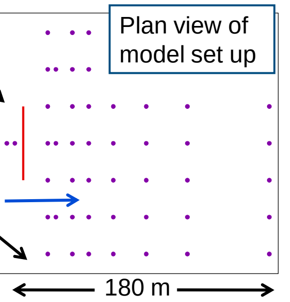
Models

Model	Meteorology	'Road' source definition	Traffic turbulence	Reference	Status
ADMS-Roads	Monin-Obukhov	Line or road	Initial σ_{z0} plus allowed for in dispersion	McHugh et al., 1997	UK model for dispersion from road sources
AERMOD	Monin-Obukhov	Area & volume*	Initial user-defined σ_{z0}	Cimorelli et al., 2005	US EPA regulatory model for short range dispersion
CALINE4	Pasquill Gifford	Line	Initial σ_{z0}	Benson, 1989	California's model for detailed project-level CO analyses
RLINE	Monin-Obukhov	Line	Initial user-defined σ_{z0}	Snyder et al., 2013	US EPA research tool

* New version of AERMOD can model 'line' sources (Oct 2012)

Idaho Falls Study
Experiment Description





- 1m high line source made up of tiny point sources
- Low level release and monitors (1 m and 1.5 m)
- Tracer gas SF_6 release: inert and passive gas
- Flat terrain
- Wind speed, turbulence and temperature data at 3 heights
- Array of 58 concentration monitors, 15 minute sampling
- Experiments with and without 'noise barrier' (initial modelling only for experiments without barrier)

Meteorological data summary

Test 1: 9-Oct-2008, 12:30 –15:30 MST, **neutral conditions** (winds > 5 m/s, overcast)

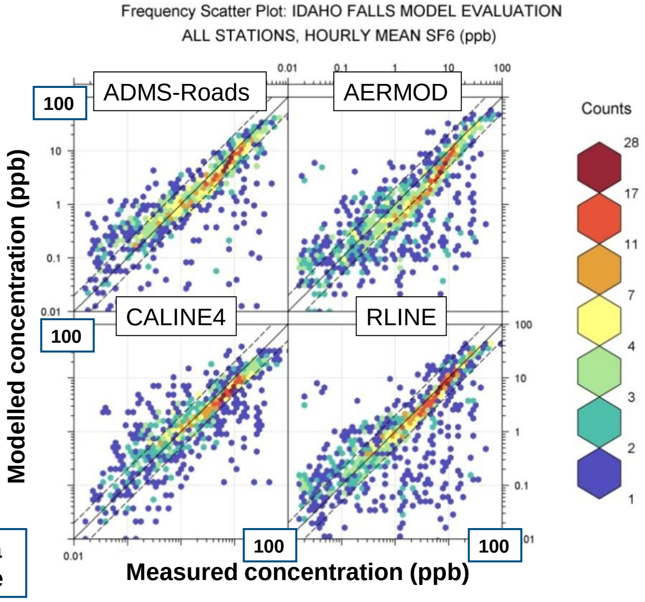
Test 2: 17-Oct-2008, 13:00 –16:00 MST, **convective conditions**, light winds

Test 3: 18-Oct-2008, 16:00 –19:00 MST, **weakly stable** conditions

Test 5: 24-Oct-2008, 18:00 –21:00 MST, moderate to **strongly stable** conditions

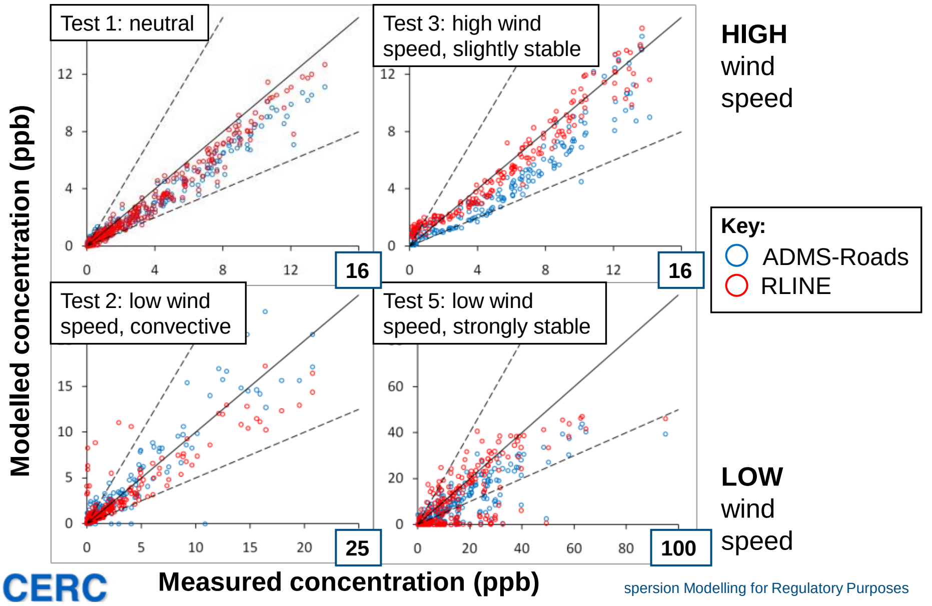
Idaho Falls Study
Results: Frequency scatter plot, all models, all data

- All test results for all models
- Frequency scatter plot on log scale created in Myair Toolkit
- Points paired in space and time
- Majority of results within a factor of 2 of the observations (dashed lines)



Plot on a log scale

Idaho Falls Study
Results: Scatter plots, ADMS-Roads & RLINE, each test



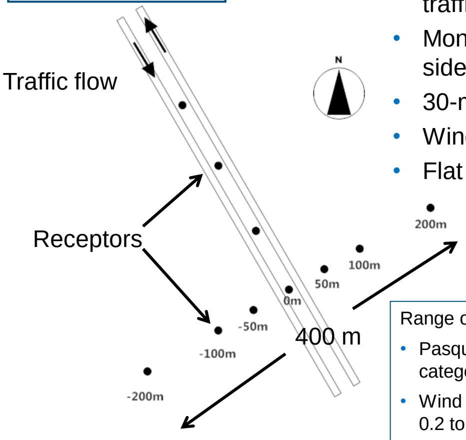
Idaho Falls Study
Results: summary statistics

Model	Fractional Bias	NMSE	Correlation	Factor of 2
ADMS-Roads	-0.37	1.16	0.88	0.69
AERMOD (area)	-0.33	1.26	0.82	0.58
AERMOD (volume)	-0.37	1.26	0.84	0.58
CALINE4	-0.42	1.97	0.76	0.58
RLINE	-0.22	0.96	0.84	0.72

- All models have a tendency to slightly underestimate concentrations (note bias sign convention opposite to BOOT, as calculated in Myair Toolkit).
- Correlation is very good for all models (over 75%).
- All models have over 55% of predictions within a factor of 2 of the observations.
- Statistics for RLINE better than for the other models (apart from Correlation, which is best for ADMS-Roads); this dataset was used in the formulation of the vertical dispersion curves for RLINE.

Caltrans Study
Experiment Description

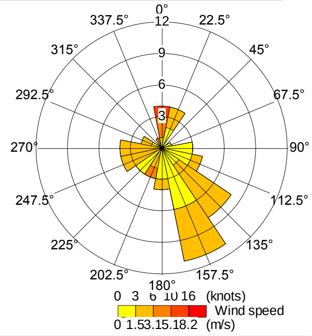
Experimental set up (early 1980's)



- 8 vehicles with SF_6 release travelling in normal traffic on a 2-lane motorway (Highway 99, daily traffic 35 000 vehicles per day)
- Monitors in the central reservation and either side of the road
- 30-minute sampling periods
- Wind speed measurements at two heights
- Flat terrain

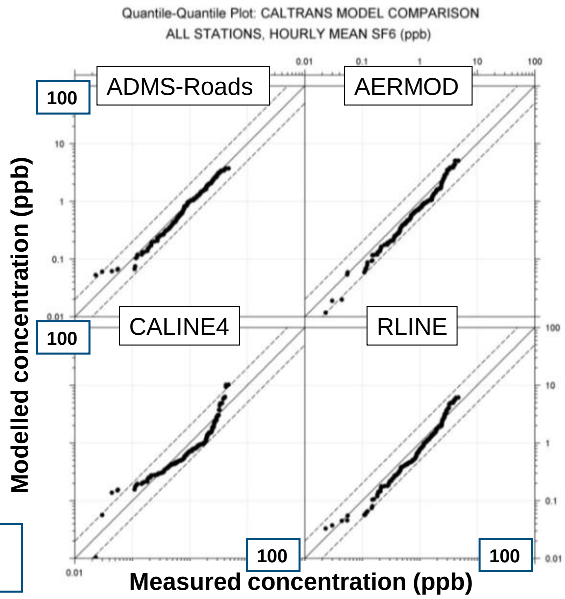
Range of met conditions:
- Pasquill-Gifford stability categories B to G
- Wind speeds at 11.4m: 0.2 to 6.0 m/s
- Prevailing wind along the road

Meteorological data summary



Caltrans Study
Results: Quantile-quantile plot, all models, all data

- All test results for all models
- Quantile-quantile plot on log scale created in Myair Toolkit
- Points not paired in space and time
- Model performance good for 'new-generation' models (ADMS-Roads, AERMOD and RLINE)



Plot on a log scale

Caltrans Study
Results: summary statistics

Model	Fractional Bias	NMSE	Correlation	Factor of 2
ADMS-Roads	-0.09	0.20	0.78	0.85
AERMOD (area)	-0.13	0.31	0.72	0.76
AERMOD (volume)	-0.15	0.28	0.77	0.78
CALINE4	-0.19	0.86	0.47	0.68
RLINE	-0.05	0.34	0.75	0.78

- All models have a tendency to slightly underestimate concentrations (note bias sign convention opposite to BOOT, as calculated in Myair Toolkit).
- Correlation is good for all models (over 70%), except CALINE.
- All models have over 65% of predictions within a factor of 2 of the observations; new-generation models over 75%.
- Statistics for ADMS-Roads better than for the other models, apart from Fractional Bias, which is best for RLINE.
- This dataset was used in the formulation of the CALINE model.

Comparisons between models and datasets

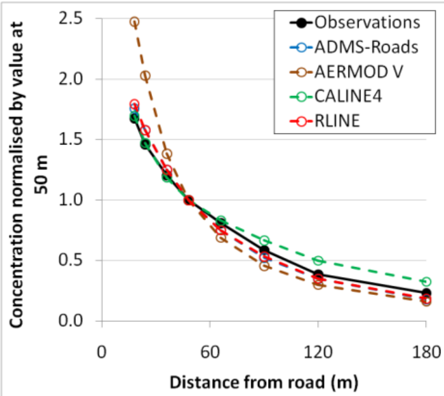
Compare:

- concentrations directly to look at how model behaviour compares to the observations (concentration decay away from the line/road source);
- statistics derived from the model and observed data; and
- graphs that show the model accuracy figuratively (NMSE/FB plot, Target plot).

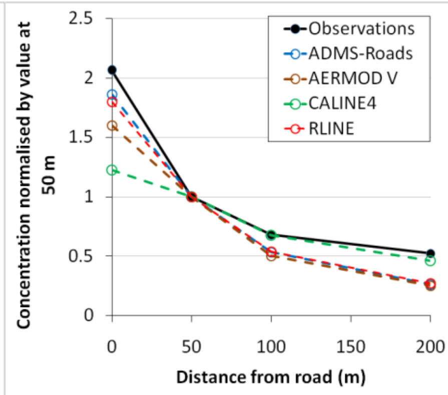
Do the different comparison approaches reach the same conclusions?

Comparisons between models and datasets
Concentration decay with distance

Idaho Falls : Line source



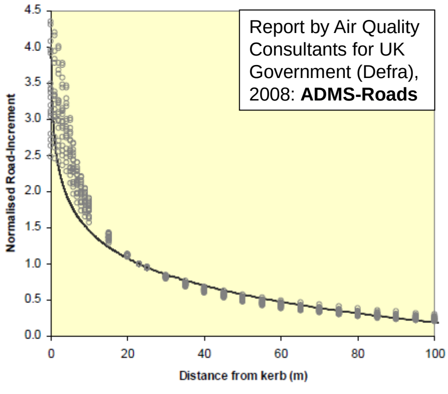
Caltrans : Road source



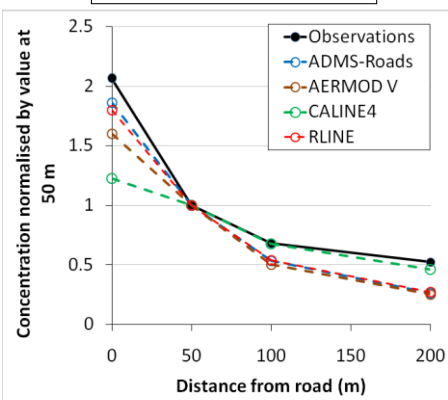
- All values normalised at 50m (observations by observations, modelled by modelled)
- ADMS-Roads and RLINE are virtually indistinguishable
- Caltrans used in the development of CALINE4

Comparisons between models and datasets
Concentration decay with distance

Road source NO_2 monitors



Caltrans : Road source



- All values normalised 23m/50m (observations by observations, modelled by modelled)
- ADMS-Roads results fit the NO_2 measurement decay reasonably well

Comparisons between models and datasets
Overall statistics

- Compare model statistics between the two experiments

Idaho Falls : line source

Model	Fractional Bias	NMSE	Correlation	Factor of 2
ADMS-Roads	-0.37	1.16	0.88	0.69
AERMOD (area)	-0.33	1.26	0.82	0.58
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Caltrans : road source

Model	Fractional Bias	NMSE	Correlation	Factor of 2
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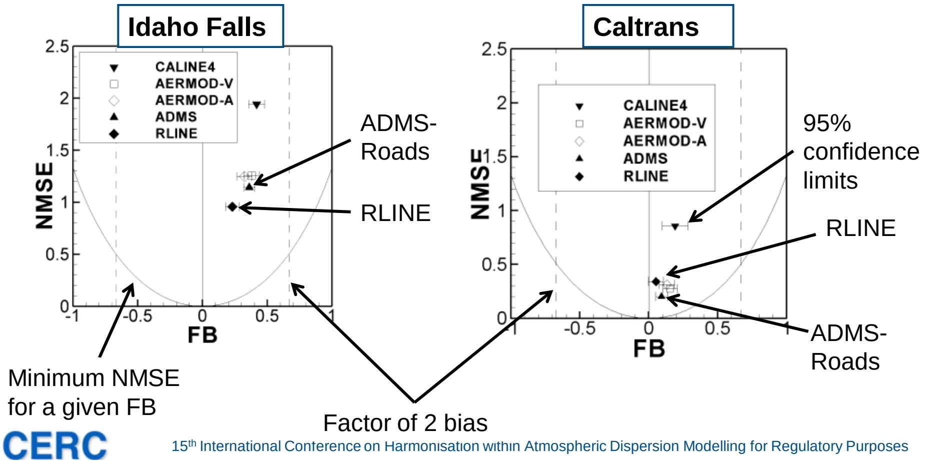
- All statistics better for Caltrans than for Idaho Falls, except for Correlation.
- Caltrans looks at downwind dispersion; Idaho Falls looks at crosswind and downwind dispersion
- Idaho Falls 'more difficult' but correlation good – due to accurate model input data?

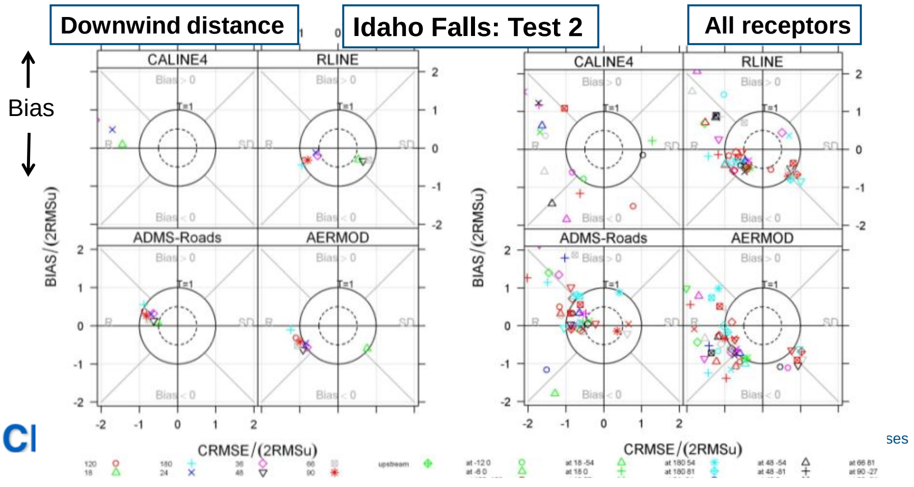
Comparisons between models and datasets
NMSE vs FB

- Look at all data points together
- Ideal model has (FB,NMSE) = (0,0)
- FB > 0 for this plot indicates the underestimation of all models



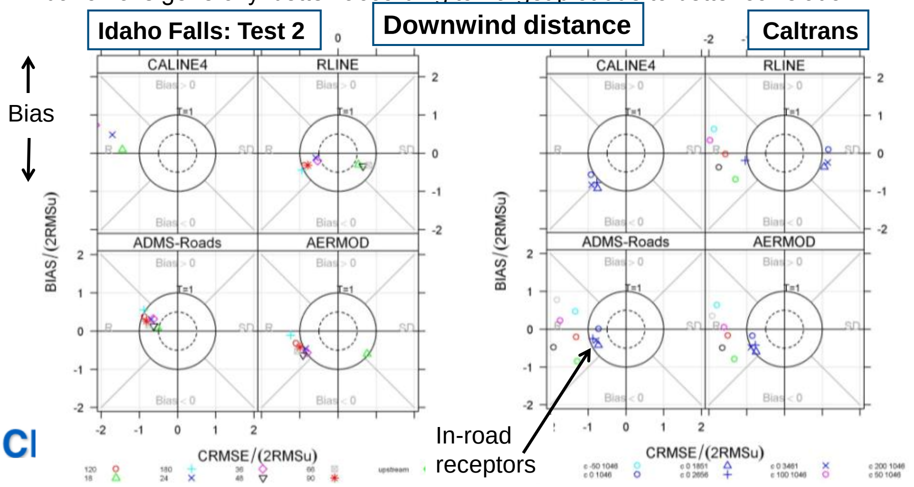
Comparisons between models and datasets
Target plots

- Idaho Falls has associated uncertainties derived for each experiment
- Model performance can be assessed using a Delta version 3.3 Target plot (implemented in the Myair Toolkit)
- Model results within the measurement uncertainty if within the inner dashed circle



Comparisons between models and datasets
Target plots

- Idaho Falls has associated uncertainties derived for each experiment
- Caltrans has no uncertainty specified – assume 10%
- When binned according to downwind distance, Caltrans best for in-road receptor
- Idaho Falls generally 'better' according to Target plot due to better correlation



Conclusions

Experiments

- New and old experimental datasets useful for model validation
- New datasets have more detailed and reliable measurements
- Idaho Falls line source experiment useful for investigation of crosswind as well as downwind dispersion

Model performance

- Models perform reasonably well, particularly the new-generation models
- Most challenging met conditions for modelling: stable and low wind speed

Model intercomparisons

- Downwind decay fits well for line source; comparison in general less good for road source; may be issues with model input data
- Statistics indicate that the model performance better when just looking at downwind dispersion (Caltrans) compared to crosswind and downwind dispersion (Idaho Falls)
- NMSE-FB plot and target plot show conflicting 'better' model performance – which is 'right'?

Further work

Experiments

- Modelling barriers and depressed roadways: experiment at Idaho Falls & wind tunnel data
- Las Vegas dataset

Model performance

- RLINE being developed to include depressed roadways, roadside barriers and an analytical solution for line sources.
- ADMS-Roads being developed with improved modelling of street canyons