Yale 耶鲁大学-南京信息工程大学大气环境中心
Yale-NUIST Center on Atmospheric Environment

A discussion on the paper "Estimates of CO_2 traffic emissions from mobile concentration measurements"

By H. L. Maness, M. E. Thurlow, B. C. McDonald and R. A. Harley

Journal of Geophysical Research : Atmospheres

Zhang Xue
2015-6-12

Outline

- Introduction
- Materials and Methods
- Results and Analysis
- Discussion

Introduction

- Urban area plays a disproportionately large part **(>70%)** of fossil fuel CO_2 emission in the worldwide range [Duren and Miller, 2012]. Within the urban core, The **dominant source of emissions** often is the traffic [Erickson et al., 2013].

- There are several challenges:

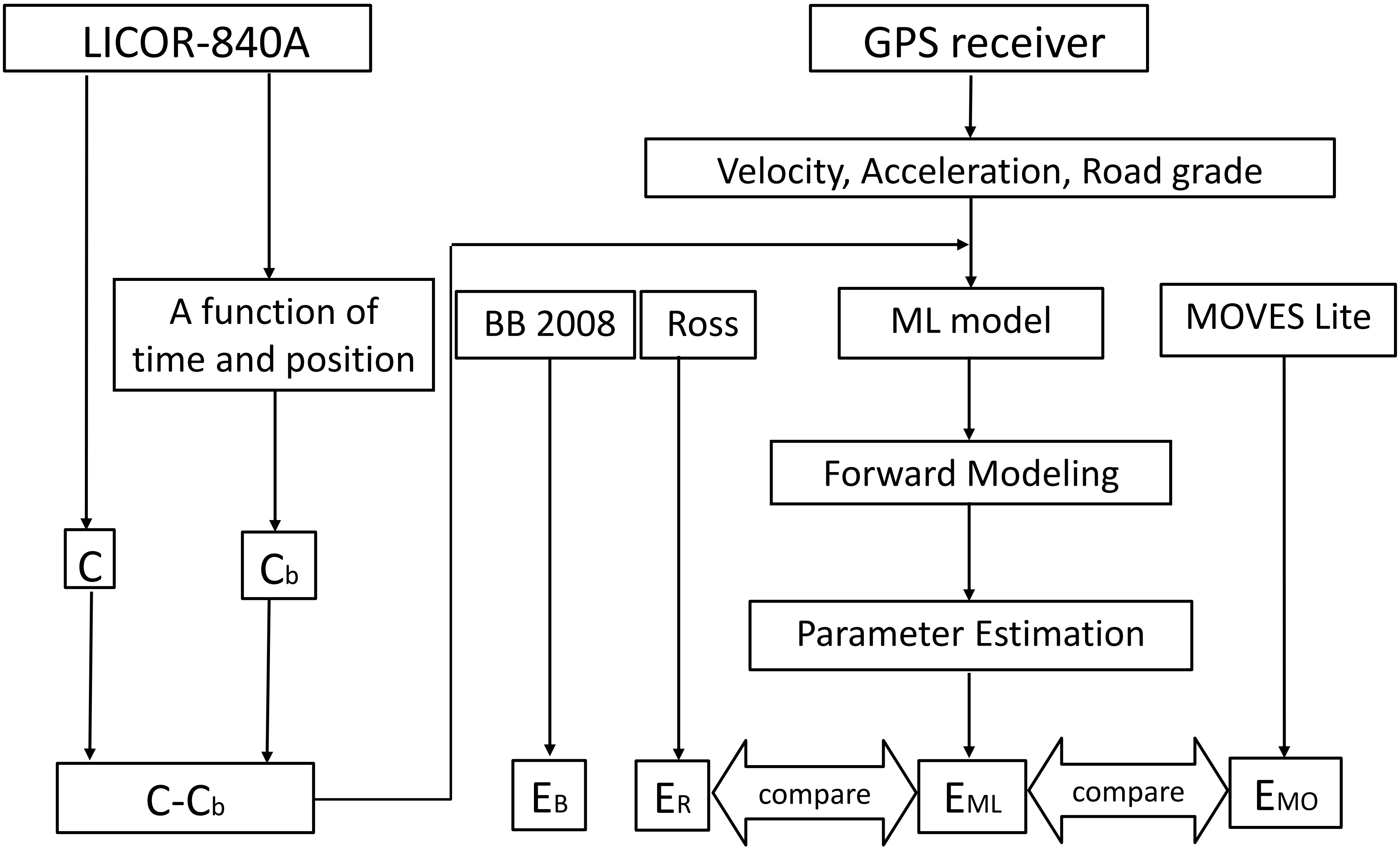
  1. Concentration data requires **a high spatial and temporal resolution**.
  2. The influence of **traffic conditions** on the boundary conditions for CO_2 dilution and pollutant dispersal.

- The objective of this experiment is to **derive on-road emissions** and **develop a model** for on-road concentrations, we then use data **to infer instantaneous emission rates.**

Materials and Methods

Fig. 1 Map of trip route along California State Route 24.

Materials and Methods



Materials and Methods

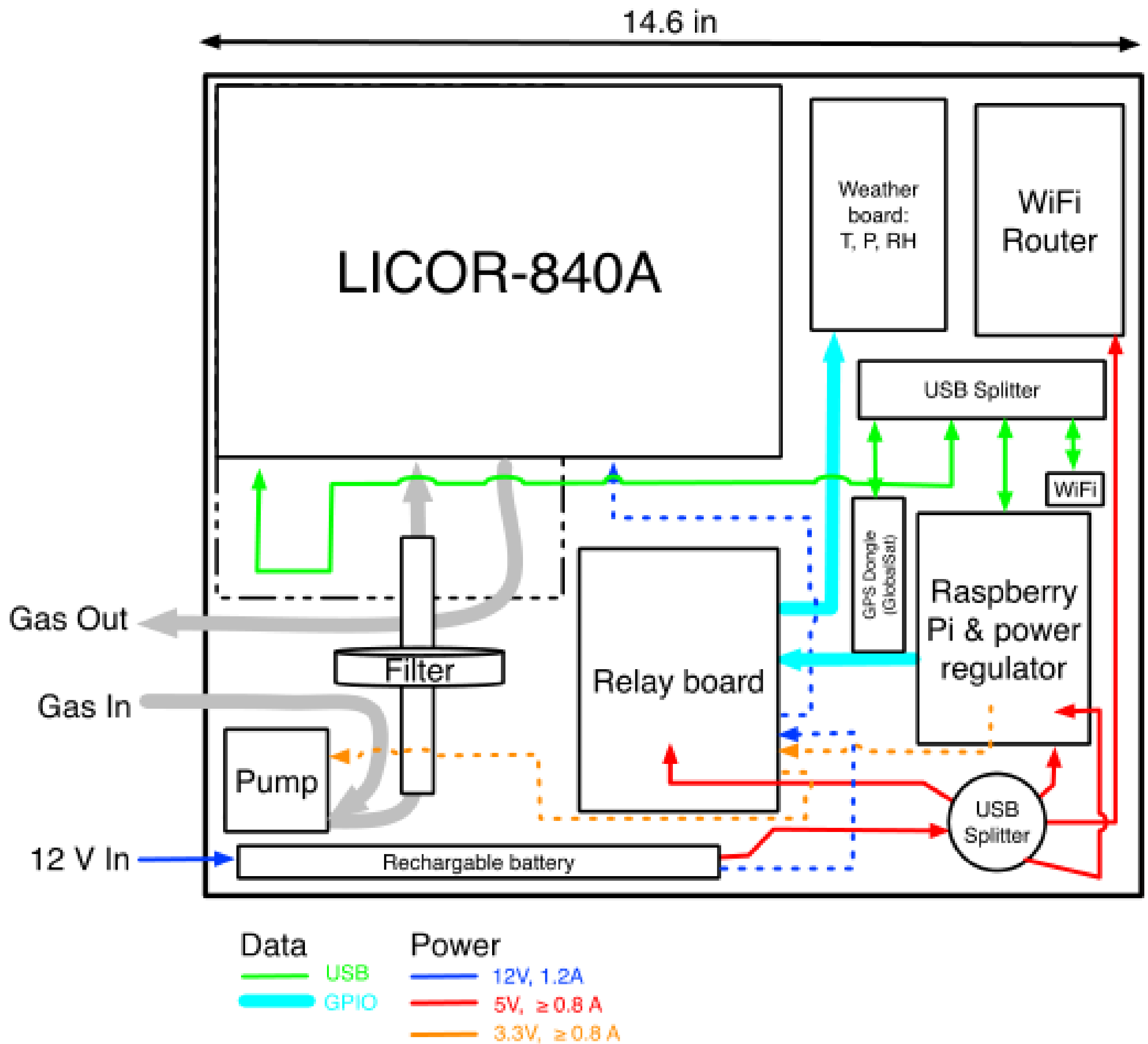


Fig. 2 Illustration of prototype node used in this experiment.

Materials and Methods

Model for Roadway CO_2 Concentration

$$C - C_b \propto F E v^{-4/3}$$ (Baker, 1996)

$$F = \frac{v}{d} N_{lanes} \qquad d^{-1} = \left(\frac{W_{car}/2}{\tan\left(\theta_{car}/2\right)} + l_{car} - l_{cam} \right)^{-1}$$

$$C - C_b = \kappa \frac{E N_{lanes}}{d} v^{-1/3}$$

Total highway emissions : $Q = \frac{E N_{lanes}}{d}$

$$C - C_b = \kappa Q v^{-1/3}$$

Materials and Methods

Model for Roadway CO_2 Concentration

$$Q = \frac{EN_{\mathrm{lanes}}}{d}$$

The per car emission rate: $E = P_{\mathrm{f}} f_{\mathrm{c}} f_{\mathrm{oxid}} f_{\mathrm{m}}$

The vehicle fuel consumption rate:

$$P_{\mathrm{f}} = \frac{1}{\eta_{\mathrm{t}}}\left(\frac{f_0 VN}{2000} + P_{\mathrm{acc}} + \frac{1-c}{\varepsilon} H\left\{P_{\mathrm{load}}\right\}\right)$$ (Ross, 1994, 1997)

The engine speed : $N = \frac{f_{\mathrm{N}}}{1+\left(v / v_{\mathrm{t}}\right)^{-6}} + N_{\mathrm{idle}}$

(Thomas and Ross, 1997)

Materials and Methods

Model for Roadway CO_2 Concentration

The engine load: $P_{\mathrm{load}} = P_{\mathrm{roll}} + P_{\mathrm{air}} + P_{\mathrm{inertia}} + P_{\mathrm{grade}}$ (Ross, 1997)

$$P_{\mathrm{roll}} = C_{\mathrm{R}} M g v \qquad P_{\mathrm{air}} = 0.5 \rho C_{\mathrm{d}} A v^3 / 1000$$

$$P_{\mathrm{inertia}} = f_{\mathrm{i}} M v a \qquad P_{\mathrm{grade}} = M g v \sin\theta$$

$$C - C_{\mathrm{b}} = N_{\mathrm{lanes}} v^{-1/3} d^{-1} \left(k_{\mathrm{fro,acc}} + k_{\mathrm{fro,N}} \frac{1}{1 + (v/v_{\mathrm{t}})^{-6}} + H\left\{ k_{\mathrm{roll}} v + k_{\mathrm{air}} v^3 + k_{\mathrm{inertia}} v a + k_{\mathrm{grade}} v \sin\left(\tan^{-1}\theta\right) \right\} \right)$$

Table 1. Model Parameter Summary[a]

Coefficient	Definition	Prior Bounds	Result	Result/Expected[b]
$k_{\mathrm{fr0,acc}}$	$\kappa \frac{f_c f_{\mathrm{oxid}} f_m}{\eta_t} \left(\frac{f_0 V N_{\mathrm{idle}}}{2000} + P_{\mathrm{acc}} \right)$	12–3200	$98.0^{+10.4}_{-10.0}$	0.20
$k_{\mathrm{fr0,N}}$	$\kappa \frac{f_c f_{\mathrm{oxid}} f_m}{\eta_t} \frac{f_0 V}{2000} f_N$	14–5400	757^{+19}_{-18}	1.2
k_{roll}	$\kappa \frac{f_c f_{\mathrm{oxid}} f_m}{\eta_t} \frac{1-\epsilon}{\epsilon} C_R M g$	2.0–200	$64.1^{+2.6}_{-3.4}$	3.0
k_{air}	$\kappa \frac{f_c f_{\mathrm{oxid}} f_m}{\eta_t} \frac{1-\epsilon}{\epsilon} \frac{0.5 \rho C_D A}{1000}$	0.0050–0.30	$0.0586^{+0.0040}_{-0.0033}$	0.91
k_{inertia}	$\kappa \frac{f_c f_{\mathrm{oxid}} f_m}{\eta_t} \frac{1-\epsilon}{\epsilon} f_i M$	30–1100	215^{+3}_{-3}	0.87
k_{grade}	$\kappa \frac{f_c f_{\mathrm{oxid}} f_m}{\eta_t} \frac{1-\epsilon}{\epsilon} M g$	280–10000	1800^{+13}_{-13}	0.77

[a]Results correspond to 16%, 50%, and 84% in the marginalized distributions.
[b]Assumes $\kappa = 0.00137$ (see text).

Materials and Methods

Model for Roadway CO_2 Concentration

$$C - C_{\mathrm{b}} = \kappa N_{\mathrm{lanes}} v^{-1/3} d^{-1} \left(E_{\mathrm{fro,acc}} + E_{\mathrm{fro,N}} + E_{\mathrm{roll}} + E_{\mathrm{air}} + E_{\mathrm{inertia}} + E_{\mathrm{grade}} \right)$$

fro, acc : accessories and idling engine friction at zero load

fro, N : the increase with engine speed in engine friction at zero load

roll : rolling resistance

air : air drag

inertia : inertia

grade : road grade

Results and Analysis

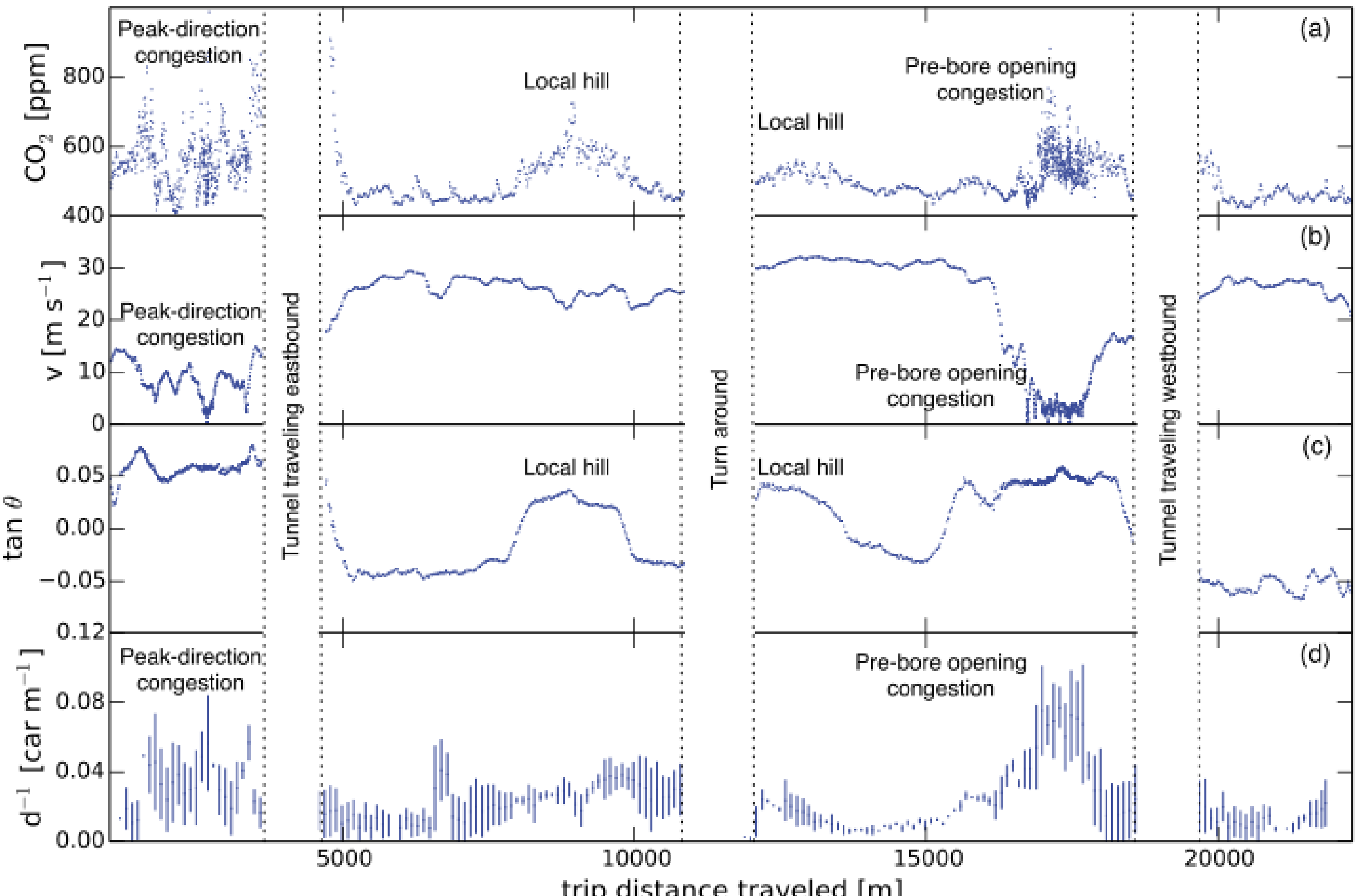


Fig. 3 Example data sequence for one evening trip made prior to the opening of the fourth bore.

Results and Analysis

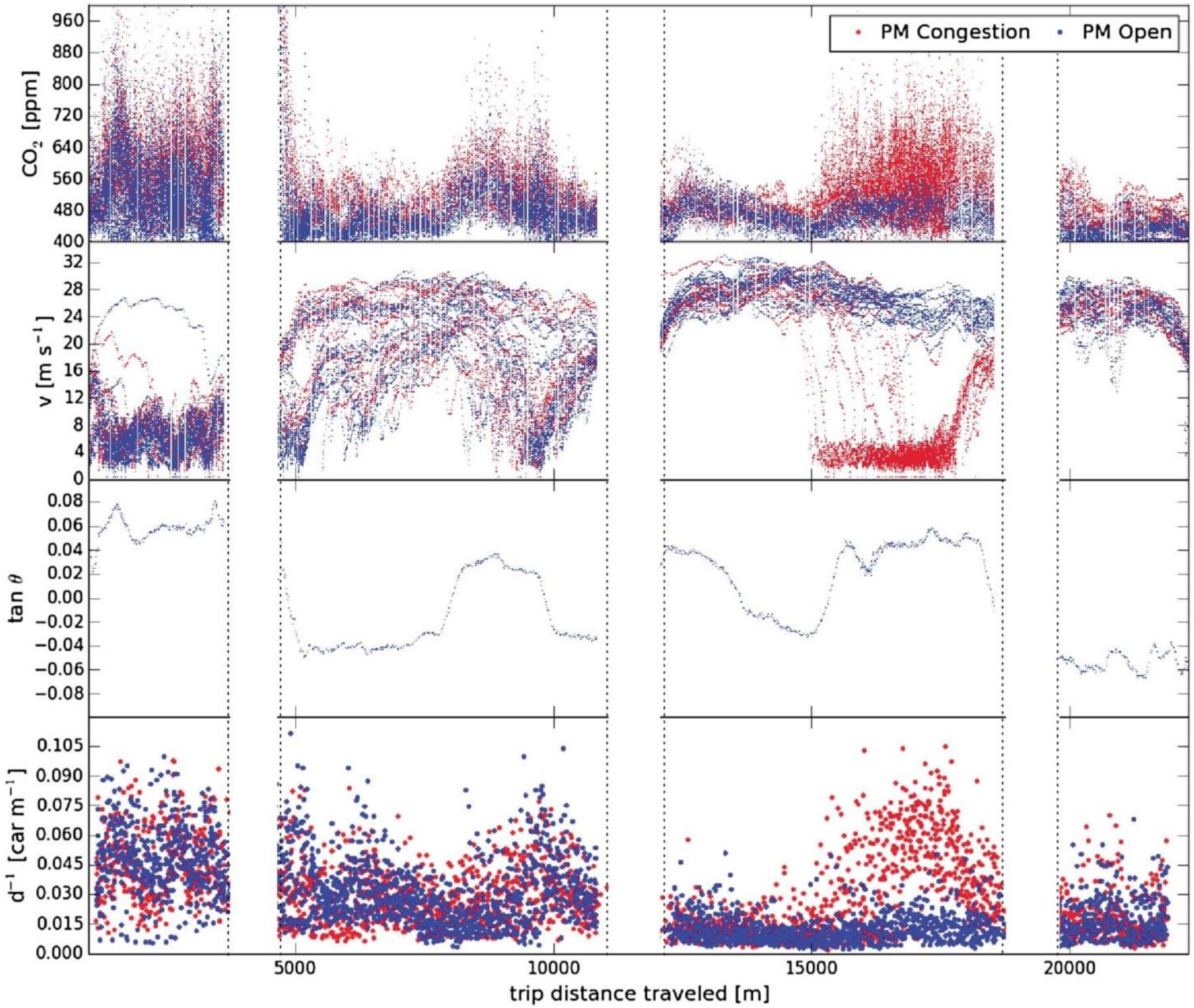


Fig. 4 Example data sequence for the full evening data set made prior to the opening of the fourth bore.

Results and Analysis

Forward Modeling

- **Q**, the total highway surface emission rate, is relatively **insensitive to congestion**, because Q is approximately independent of vehicle speed.
- The **velocity correction** for vehicle-induced turbulence does a reasonable job of predicting concentrations.

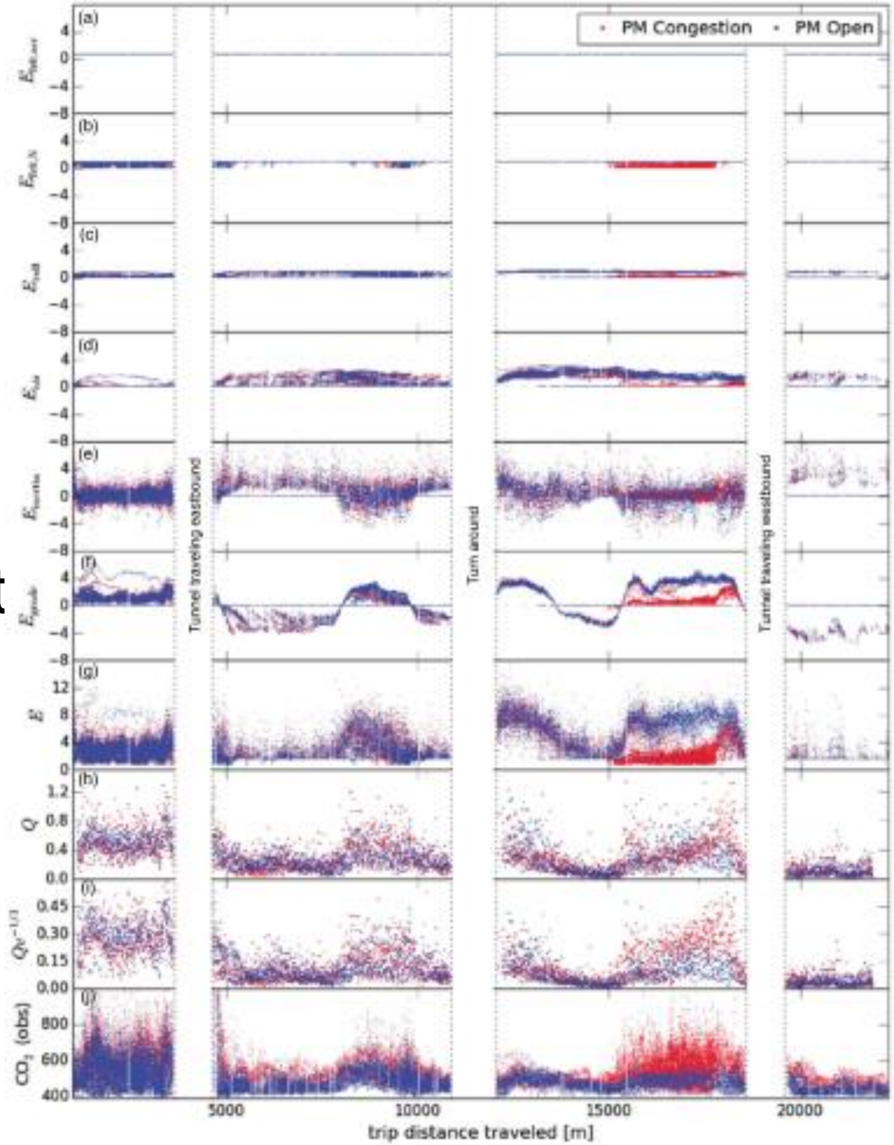


Fig.5 Forward modeling results for all evening data.

Results and Analysis

Parameter Estimation

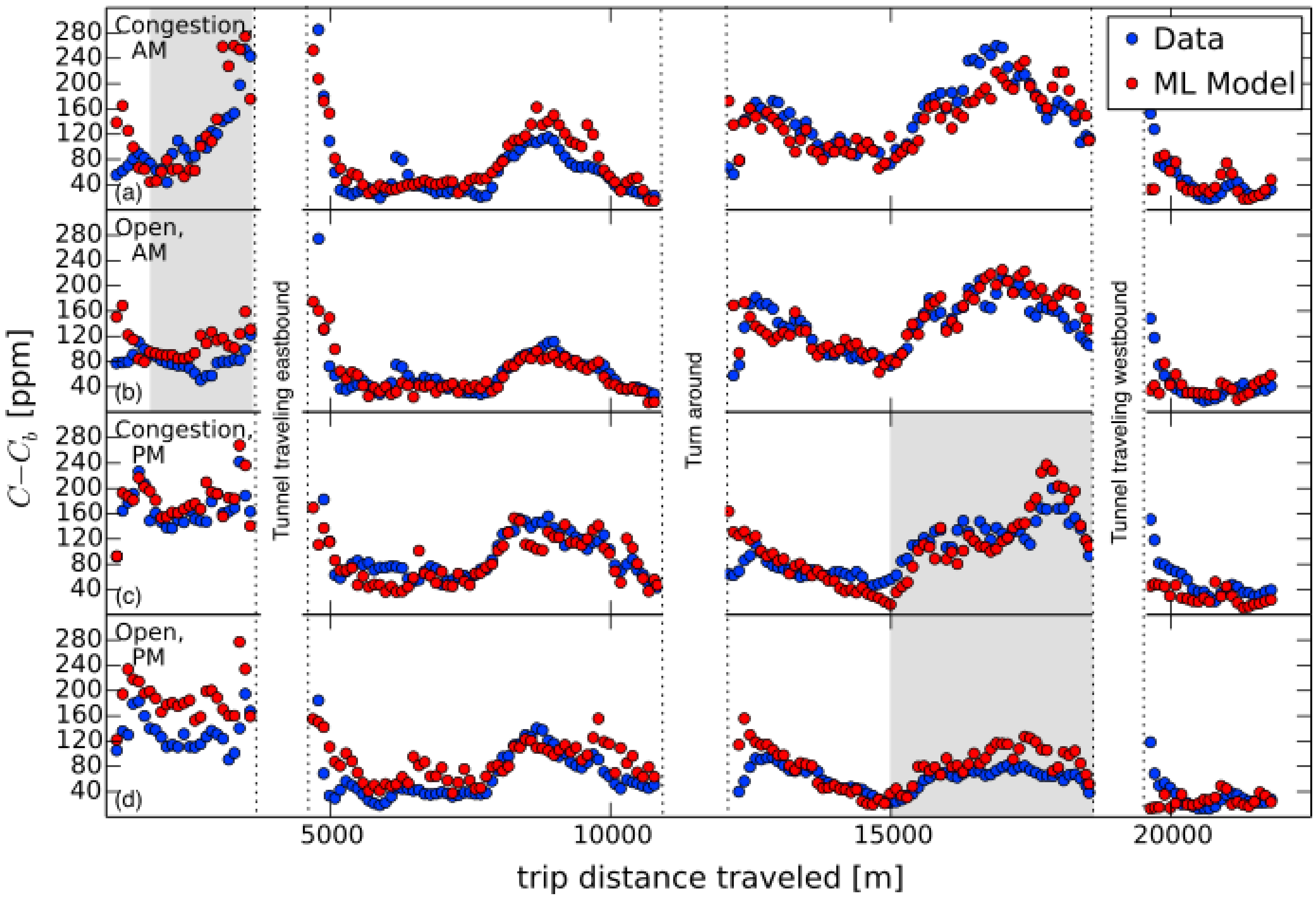


Fig. 6 Comparison of the Highway 24 concentration data above background to the maximum likelihood model.

Results and Analysis

Parameter Estimation

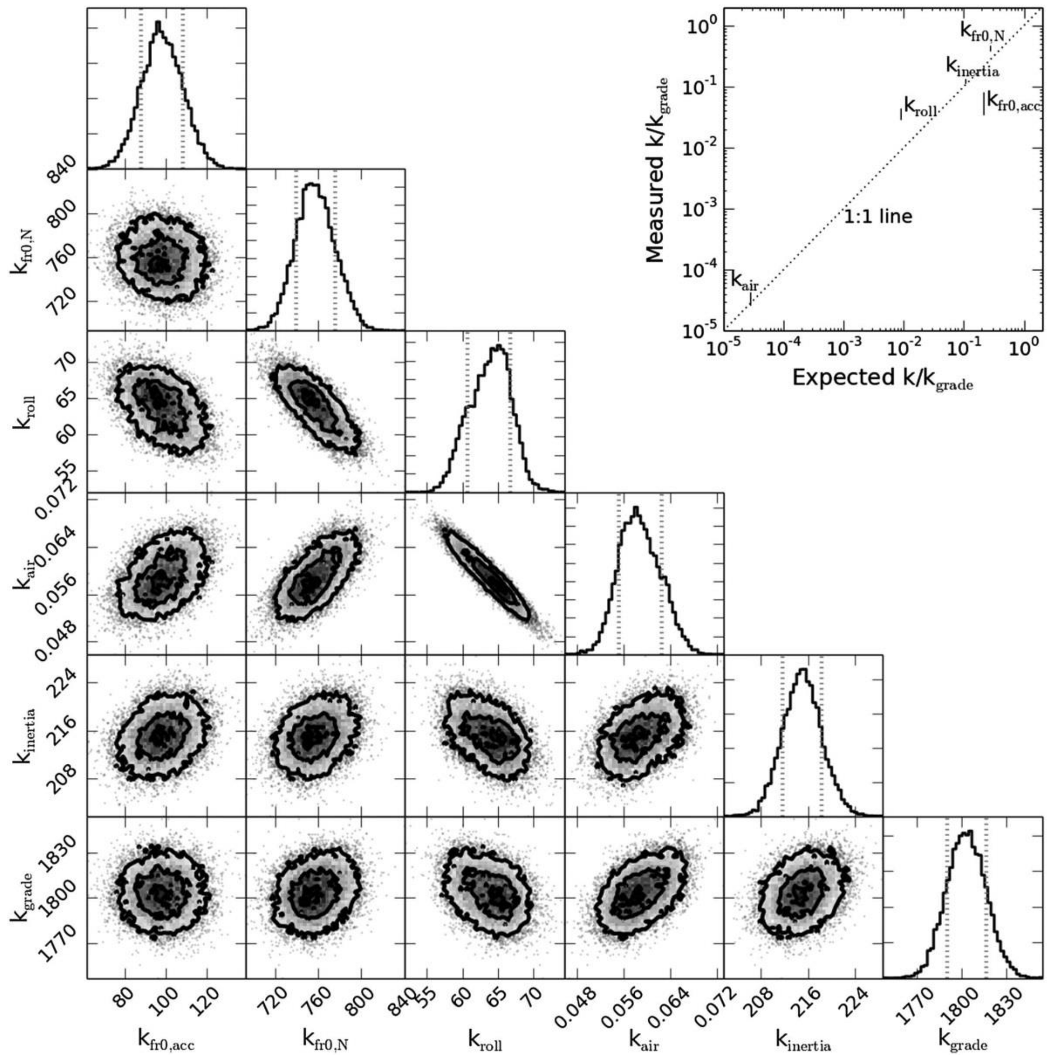


Fig. 7 The distributions and correlations for the emissions rate constants.

Results and Analysis

Three emissions models

- **Ross model** : velocity, acceleration, and road grade [Ross, 1994, 1997]

- **BB08** : its only input is speed [Barth and Boriboonsomsin, 2008]

- **MOVES Lite** : velocity, acceleration, and road grade [Frey and Liu, 2013]

Results and Analysis

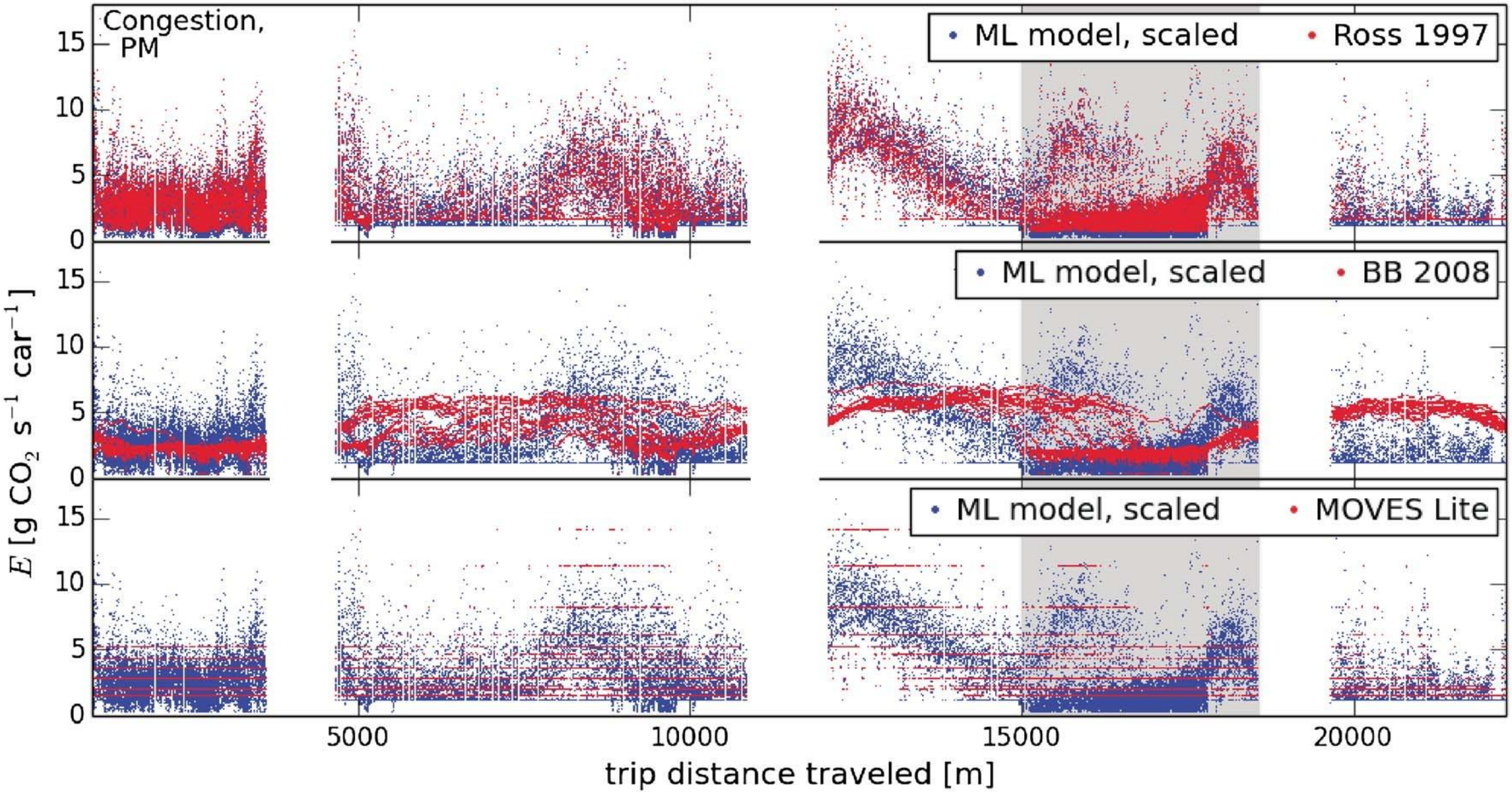


Fig. 8 Instantaneous vehicle emission rates for our maximum likelihood model compared to three alternative models presented in the literature.

Results and Analysis

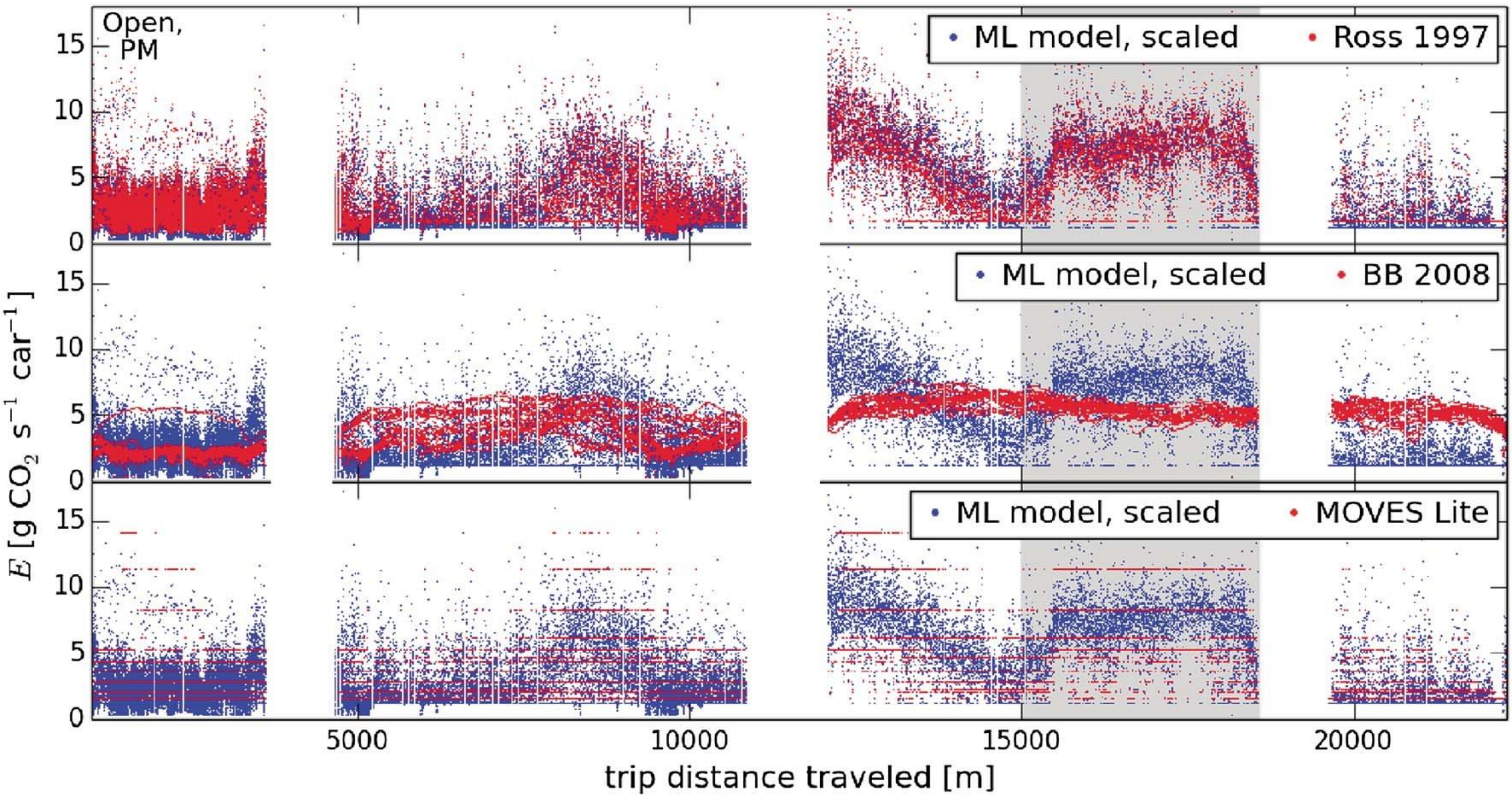


Fig. 9 Same as Figure 8 only for the period after the fourth bore is open.

Discussion

- Mobile concentration measurements in this paper can be **a promising and useful method/dataset** for testing, improving existing emission models when traffic and fleet information are readily available.

- For the application in this paper, **further work** will focus on improving the derivation of baseline emission rates and extending the transport modeling to predict absolute (rather than relative) emission rates.

Thank you