PERFORMANCE EVALUATION OF CAL3QHC AND CALINE4 FOR SHORT-TERM SIMULATION OF FINE PARTICULATE MATTER AND CARBON MONOXIDE CONCENTRATIONS AT A ROAD INTERSECTION

Dongsheng Wang, Ph.D. Student
Center for UAV Applications and ITS Research
School of Naval Architecture, Ocean & Civil Engineering
Shanghai Jiao Tong University
800 Dongchuan Rd., Shanghai 200240, China
E-mail: aquamarine_wds@126.com

Zhanyong Wang, Ph.D. Student
Center for UAV Applications and ITS Research
School of Naval Architecture, Ocean & Civil Engineering
Shanghai Jiao Tong University
800 Dongchuan Rd., Shanghai 200240, China
E-mail: wangzy1026@163.com

Zhong-Ren Peng*, Ph.D., Professor
Center for UAV Applications and ITS Research
State Key Laboratory of Ocean Engineering
School of Naval Architecture, Ocean & Civil Engineering
Shanghai Jiao Tong University
800 Dongchuan Rd., Shanghai 200240, China
And
Department of Urban and Regional Planning
University of Florida
P.O. Box 115706, Gainesville, FL 32611-5706, USA
Tel: +8602134206674; E-mail: zpeng@dcu.ufl.edu

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*Corresponding author
ABSTRACT
At road intersections, pedestrians are frequently exposed to high level of air pollutants, and the effective estimation is thus critical for relieving the health risk in such a microenvironment. Although a series of deterministic models have been used to estimate the concentrations of air pollutants at intersections recently, they are limited to the original purpose of most simulation models to simulate the average behavior of the dispersion process of vehicular pollutants at longer time scale such as daily and hourly. While pollutant levels can vary with traffic signal lights and instantaneous peaks occur between minutes, these models are thus confronting the trial of forecasting minute-scale pollution levels. Hence, this study first evaluates the performances of two typical air quality models, i.e., California Line Source Model with Queuing and Hot Spot Calculations (CAL3QHC) and California Line Source Model version 4 (CALINE4), in predictions of fine particulate matter (PM$_{2.5}$) and carbon monoxide (CO) at 5-min scale. Results show that CAL3QHC generally performs well for 5-min predictions of both PM$_{2.5}$ and CO compared with CALINE4. Besides, both models perform better at off-peak than peak periods, which can be attributed to the fluctuation of high traffic volumes as well as the more complex mechanical turbulence induced by passing vehicles in peaks. Furthermore, performances of both models are more related to wind speed particularly when predicting CO concentrations. When wind speed is less than 1m/s, both models will have better performances. The outputs of these findings demonstrate the potential of both models to be applied to forecast the real-time trends of air pollution as well as to capture the extreme values due to varied scenarios at road intersections.

Keywords: Fine particulate matter, Carbon monoxide, CAL3QHC, CALINE4, Short-term estimation, Road intersection
1. INTRODUCTION

In urban area, people are suffering from health risks induced by ambient air pollution, which is mainly caused by vehicle emissions. Road intersections are more contaminated due to large variations in traffic, such as traffic flow (free, interrupted, or congested), vehicular state (idle, acceleration, deceleration, cruise, etc.), vehicle type (cars, buses, trucks, etc.) (1, 2, 3, 4). Hence, it is necessary to better understand the air pollution at intersections using an appropriate method.

Up to date, some approaches have already been used to evaluate air pollutants levels at intersections. For example, computational fluid dynamics (CFD) models are used to simulate the dispersion of air pollutants at intersections but the modeling results of them are less validated compared to the real field measurements (5); line source dispersion models, such as M-GFLSM, CAL3QHC, and CALINE4 have also been applied for the estimation of pollutants concentrations at intersections with the acceptable results in current studies while these models just demonstrate their feasibility of forecasting air pollutants at longer time scales such as daily and hourly (6, 7, 8, 9). As we know, due to the complex traffic conditions and variable meteorology, air pollutants dispersions could be more complex around intersections in comparison with other traffic environments (10). Moreover, the concentrations of air pollutants at road intersections have been proved to vary in minutes due to the influence of traffic signal lights (11, 12, 13), which inevitably increases the complexity of pollutants predictions. As the more and more serious adverse health consequences of short-term exposures to high pollution levels have been identified (14), few studies have focused on the fine-scale (e.g., minute-scales) evaluation of air pollutants yet. Hence, it is necessary and vital to test whether the present models are suitable for the fine-scale estimation.

This paper attempts to estimate the performances of two popular air quality models (i.e., CAL3QHC and CALINE4) used to predict air pollutants levels at 5-min scale) at a suburban intersection in Shanghai and the study is conducted with comparisons at three time periods (i.e., morning and afternoon peaks, midday) as well as distinguishing wind speeds. Two typical traffic-related air pollutants (i.e., fine particulate matter (PM$_{2.5}$) and carbon monoxide (CO)) were selected here. PM$_{2.5}$ is not only an immediate product of traffic emissions but also a secondary product by physical and chemical reactions (15). Conversely, CO is a stable gaseous pollutant and mainly contributed by engine combustions, its structure could hardly be changed in the outdoor environments (12). These two pollutants with different nature can be used to further examine the sensitivity of the two models to different pollutants.

In this study, two line source dispersion models used for estimation 5-min average of PM$_{2.5}$ and CO concentrations at an intersection are introduced in Section 2. Field measurement campaigns and methodology are then described in Section 3, and results and discussions follow in Section 4. Finally, conclusion and limitations are presented in Section 5.

2. LINE SOURCE DISPERSION MODELS

2.1 CAL3QHC

CAL3QHC (California Line Source Model with Queuing and Hot Spot Calculations) is an enhanced version of CALINE3, which is the third version of CALINE series models. This
model is mainly used for signal controlled intersections, for it has additional methods to estimate queue lengths and emissions from idling vehicles. CAL3QHC can be used for estimation of PM and CO concentrations near signal controlled intersections, and model comparison studies have shown its capability in estimating PM and CO concentrations near intersection or traffic flow. (16)

The primary input parameters for CAL3QHC include emission factor, traffic parameters (such as the traffic volume, signal type, and saturation flow rate), meteorological parameters (such as the wind speed and mixing height) and site position.

2.2 CALINE4
CALINE4 (California Line Source Model version 4) is the fourth advanced version of CALINE series models. The dispersion algorithms used in CALINE series model are based on a modified form of a Gaussian point source plume (17). CALINE4 can be used to predict roadside concentration of carbon monoxide, nitrogen oxides and particulate matters. Although CALINE4 is not considered suitable for predicting pollutant dispersion in street canyon, it has been used for concentration estimation near intersection or highway.

The input parameters for CALINE4 are similar with CAL3QHC, which include emission factor, meteorological parameters and site position. However, for traffic parameters, CALINE4 only need the traffic volume on each link, signal type are not considered in CALINE4.

3. FIELD EXPERIMENTS AND METHODOLOGY

3.1 Measurement Campaign
In this study, an intersection located in the suburb of Shanghai was selected for data collection. This signalized intersection consists of Dongchuan Road and Cangyuan Road perpendicular to each other (Figure 1). Shanghai Jiao Tong University (SJTU) sits northeast to the intersection, while residences are in other directions. There is always a congestion at this intersection at peak hour. Dongchuan Road is a four-lane road, and the traffic flow is mainly composed of cars, buses and trucks. Cangyuan Road is a two-lane road, and its traffic flow includes trucks, and also cars and buses. Due to the openness around the intersection, there is hardly a canyon effect of air pollutant dispersion. The road geometry is shown in Figure 1, together with locations of the sampling. The azimuth bearing of Cangyuan Road is 20 degrees to the north and the bearing of Dongchuan Road is 110 degrees to the north.

The whole field campaign lasted for four days in spring 2013, and daily measurement was split into peak (morning (7:00~9:00), evening (16:00~18:00)) and off-peak (midday (11:00~14:00)) periods. Experiments simultaneously referred to roadside and setback monitoring. Roadside monitoring was moveable on four corners of the intersection, from Site 1a to Site 1d in turn during every sampling period of a day, whereas as a background reference site the setback (Site 2 in Figure 1) sat on SJTU campus with about 300m northeast to the intersection.
3.2 Data Description

All the data were collected at a time scale of one minute. The 1-min average concentrations of PM$_{2.5}$ and CO were measured using portable devices (TSI Sidepak AM 510 Personal Aerosol Monitor for PM$_{2.5}$ and Langan Model T15n CO Measurer for CO). These devices were set up 1.7m above the ground, since this height is close to breathing zone of adult pedestrians. The Davis Vantage VUE Weather Station sat on SJTU campus (Site 2 in Figure 1), and it was mounted 2.5m above the ground to measure meteorological parameters, such as temperature, wind direction and wind speed. PM$_{2.5}$ and CO concentrations are presented in Figure 2a and 2b, respectively. Figure 2c shows the wind rose.

Traffic data were collected by using video cameras. All the vehicles were sorted into four types: light-duty diesel vehicles (LDDV), heavy-duty diesel vehicles (HDDV), light-duty gasoline vehicles (LDGV) and heavy-duty diesel vehicles (HDGV). The traffic volume of each vehicle type from each direction was counted, which will be used in the model application part. The total volumes of each vehicle type are shown in Figure 2d. As Figure 2d shows, the traffic flow is mainly composed by LDGV.
FIGURE 2 Data description. (a)PM$_{2.5}$ concentration (b) CO concentration (c) Wind rose (d) Volume type.

3.3 Methodology

In order to estimate the performances of CAL3QHC and CALINE4 used to predict air pollutants levels at 5-min scale, these two models were applied at the road intersection. As Figure 3 shows, there are eight links in CAL3QHC model Link A, Link B, Link C and Link D are represented for Dongchuan Road. Link A and Link B constitute one direction of Dongchuan Road, while Link C and Link D constitute another direction. Link A and Link C account for the approach part of Dongchuan Road, while Link B and D account for the departure part. Link E to H are represented for Cangyuan Road, and the meanings are similar with Link A to D. Link A, Link C and Link E, Link G are set as queue link, while the other links are set as free flow link. The total length of Link A and Link B is 2km, and the total length of Link E and F is also 2km. The positions of Site 1a to 1d (receptors) are as Figure 3 shows.

As the mixing height has a small effect on dispersion of pollutants generated from a low-level source of vehicles, the mixing height is settled to be 500m, and does not change in this model application case (18). For ambient concentration inputs, the observed concentrations at Site 2 (in Figure 1) are used for input, because there is far enough from the intersection.

In CAL3QHC model application case, we used 5-min average traffic and meteorological data to estimate short-term concentrations in five minutes. For this purpose, 5-min average meteorological data (such as temperature, wind speed and wind direction) were used as meteorological inputs. And traffic volumes on each link for inputting were converted from traffic volumes of each link in five minutes, for inputs of traffic volumes need one-hour average data.

$$V_{\text{input}} = V_{\text{5min}} \times 12 \quad (1)$$

Emission factor (EF) for free flow conditions (g · km$^{-1}$) were obtained from two studies in China (19, 20). Emission factor for idle conditions (g · h$^{-1}$) were obtained from US Environmental Protection Agency reports (21, 22). As the emission factors were for different type of vehicles, the composite emission factor was calculated by Eq. (2):
\[ EF_c = \frac{EF_1 \times V_1 + EF_2 \times V_2 + EF_3 \times V_3 + EF_4 \times V_4}{\sum V} \quad (2) \]

Where, \( V_1 \) represents the volume of light-duty diesel vehicles; \( V_2 \) represents the volume of heavy-duty diesel vehicles; \( V_3 \) is the volume of light-duty gasoline vehicles; \( V_4 \) is the volume of heavy-duty diesel vehicles. \( EF_1, EF_2, EF_3, EF_4 \) are corresponding emission factors. The composite emission factor was used as inputs of CAL3QHC model.

\[ \sum \]

**FIGURE 3 Line geometry system for CAL3QHC.**

The setting of link geometry for CALINE4 was the same as for CAL3QHC, the only difference was that all the links in CALINE4 is free flow link, for there was not a queue link setting in CALINE4. Most parameters for CALINE4, such as mixing height and emission factor, were set to be the same as for CAL3QHC. Meteorological data were 5-min average data, and traffic volume inputs were calculate by Eq. (1). The wind direction is assumed to be almost the same in 5 minutes. Thus, the input value of wind direction standard deviation is settled to be 5 degrees (the minimum acceptable value for CALINE4).

### 4. RESULTS AND DISCUSSION

#### 4.1 Overall Evaluation of CAL3QHC and CALINE4 Modeling at 5-min Scale

Predicted \( PM_{2.5} \) and CO concentrations are calculated as methodology mentioned above. Figure 4 shows the scatter-plots of observed and predicted concentrations. According to Figure 4, it seems that both CAL3QHC and CALINE4 have shown good results for estimation of \( PM_{2.5} \) concentrations, while CALINE4 shows a comparatively bad result for CO, as Figure 4b
FIGURE 4 Scatter plots of predicted concentrations. (a) PM$_{2.5}$ concentrations predicted
by CAL3QHC and CALINE4 (b) CO concentrations predicted by CAL3QHC and CALINE4.

To evaluate the performance of CAL3QHC and CALINE4 involving modeling ability and precision, various statistical indexes were presented. The absolute bias (AB) is used to evaluate the bias between predicted and observed values, while fractional bias (FB) is a dimensionless number to evaluate the bias. FB varies between -2 and +2, and 0 means that there is no bias. Root mean square error (RMSE) emphasizes the variation of the model estimation, and normalized mean square error (NMSE) is a normalized form of RMSE ranged between 0 and 1. Index of agreement \((d)\) is intended to be a descriptive measure, which can be applied in order to make cross-comparisons between models. Instead of the correlation coefficient \((r)\) or the coefficient of determination \((r^2)\), the value of \(d\) is not a correlation measure, but a measure to describe how error free the model prediction is. It ranges from 0 to 1, and the value of 1 represents a perfect agreement of the predicted and observed values, while 0 indicates a complete disagreement (23). There statistical criteria are defined by Eqs. (3)-(7):

\[
\text{AB} = \bar{P} - \bar{O} \quad (3)
\]

\[
\text{FB} = \frac{(\bar{P} - \bar{O})}{(\bar{P} + \bar{O})/2} \quad (4)
\]

\[
\text{RMSE} = \sqrt{\frac{\sum_{i=1}^{n} (P_i - O_i)^2}{n}} \quad (5)
\]

\[
\text{NMSE} = \frac{(P_i - O_i)^2}{\bar{P} \cdot \bar{O}} \quad (6)
\]

\[
d = 1 - \frac{\sum_{i=1}^{n} (P_i - O_i)^2}{\sum_{i=1}^{n} [P_i - \bar{O}]^2 + [O_i - \bar{O}]^2} \quad (7)
\]

Table 1 Performance measures of CAL3QHC and CALINE4

<table>
<thead>
<tr>
<th>Parameters</th>
<th>PM(_{2.5}) ((\mu g/m^3))</th>
<th>CO (ppm)</th>
<th>CAL3QHC</th>
<th>CALINE4</th>
<th>CAL3QHC</th>
<th>CALINE4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Absolute bias (AB)</td>
<td>-2.50</td>
<td>0.03</td>
<td>-0.74</td>
<td>0.48</td>
<td></td>
<td></td>
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<tr>
<td>Fractional bias (FB)</td>
<td>-0.04</td>
<td>0.04</td>
<td>-0.01</td>
<td>0.50</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Root mean square error (RMSE)</td>
<td>4.67</td>
<td>0.50</td>
<td>4.77</td>
<td>1.08</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Normalized mean square error (NMSE)</td>
<td><strong>0.01</strong></td>
<td>0.45</td>
<td><strong>0.01</strong></td>
<td>1.33</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Index of agreement ((d))</td>
<td><strong>0.98</strong></td>
<td>0.51</td>
<td><strong>0.98</strong></td>
<td>0.25</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 1 shows the performance measures for total data. The results show that in this case, CAL3QHC has lower RMSE and NMSE than CALINE4 for CO concentration estimation, and CAL3QHC also has lower AB and FB. The $d$ value of CAL3QHC also shown better performance than the $d$ value of CALINE4 result. For PM$_{2.5}$ concentration estimation, both CAL3QHC and CALINE4 have low RMSE and NMSE, and the $d$ value is pretty good as well. In contrast with CO concentration estimation, CALINE4 has lower AB and FB than CAL3QHC for PM$_{2.5}$ concentration estimation.

To evaluate the performances of models using at 5-min scale, the results were compared with Gokhale’s study in India (6). PM$_{10}$ and PM$_{2.5}$ concentrations were predicted at day scale by three different models, include CAL3QHC in that study. The NMSE, FB and IA of PM$_{2.5}$ results were 0.5, -0.3, and 0.5 respectively. Compared with Table 1, the performance of CAL3QHC at 5-min scale is not worse than the day-scale results, while CALINE4 does not perform well for CO.

4.2 Performance of CAL3QHC and CALINE4 with Locations and Time Periods

The results for varied location are presented in Figure 5. Both PM$_{2.5}$ and CO shows similar pattern in varied location, and there is no significant difference in performances of models in varied location.
FIGURE 5 (a to d) Comparative performances of models for PM$_{2.5}$ concentrations in varied locations. (e to h) Comparative performances of models for CO concentrations in varied locations.
FIGURE 6 (a, b, c) Comparative performances of models for PM$_{2.5}$ concentrations in varied time periods. (d, e, f) Comparative performances of models for CO concentrations in varied time periods.

Table 2 Performance measures in varied time periods

<table>
<thead>
<tr>
<th>Parameters</th>
<th>PM$_{2.5}$ (μg/m$^3$)</th>
<th>CO (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Morning</td>
<td>Midday</td>
</tr>
<tr>
<td>Absolute bias (AB)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CAL3QHC</td>
<td>-4.78</td>
<td>-0.75</td>
</tr>
<tr>
<td>CALINE4</td>
<td>-2.68</td>
<td>0.46</td>
</tr>
<tr>
<td>Fractional bias (FB)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CAL3QHC</td>
<td>-0.07</td>
<td>-0.01</td>
</tr>
<tr>
<td>CALINE4</td>
<td>-0.04</td>
<td>0.01</td>
</tr>
<tr>
<td>Root mean square error (RMSE)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CAL3QHC</td>
<td>6.61</td>
<td>2.99</td>
</tr>
<tr>
<td>CALINE4</td>
<td>6.77</td>
<td>3.23</td>
</tr>
<tr>
<td>Normalized mean square error (NMSE)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CAL3QHC</td>
<td>0.01</td>
<td>0.003</td>
</tr>
<tr>
<td>CALINE4</td>
<td>0.01</td>
<td>0.004</td>
</tr>
<tr>
<td>Index of agreement (d)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CAL3QHC</td>
<td>0.97</td>
<td>1.00</td>
</tr>
<tr>
<td>CALINE4</td>
<td>0.97</td>
<td>0.99</td>
</tr>
</tbody>
</table>

As Table 2 shows, for each time period, the performance differences between each model are similar. For CO concentration estimation, CAL3QHC has lower AB, FB, RMSE, and NMSE than CALINE4 in all the three periods, and CAL3QHC also has a higher $d$ value than CALINE4 does. As for PM$_{2.5}$ concentration estimation, CAL3QHC and CALINE4 have almost the same NMSE and $d$ value for all the time periods. The RMSE values for CAL3QHC and CALINE4 is also similar. However, CALINE4 has lower AB and FB than CAL3QHC during all the three time periods.

In Figure 6, both CAL3QHC and CALINE4 seem to perform better for PM$_{2.5}$ and CO concentration estimation during off-peak period. The performance measures indicated similar results. For CO, both CAL3QHC and CALINE4 have lowest AB and FB during off-peak
period. Moreover, both the two models have lowest NMSE and RMSE during off-peak period. The $d$ value of CAL3QHC also takes the highest value during off-peak period. CALINE4 have a higher $d$ value of 0.34 at morning peak, and the $d$ value of off-peak period is 0.25, while the $d$ value of evening peak is the lowest. For PM$_{2.5}$, there are similar results. Both models have lowest AB, FB, and NMSE, RMSE at noon hours, and have highest $d$ value, as well.

The performance measures indicated that both CALINE4 and CAL3QHC perform better during off-peak period. Different from peak hours, the volumes in midday are smaller and relatively stable, which can explain the performance difference. That is to say, as the predicted concentration is a 5-min average value, if there is a significant fluctuation of traffic volume, the dispersion models may not work well.

### 4.3 The Impacts of Wind on Modeling Results of CAL3QHC and CALINE4

As line source dispersion models typically do not perform well under low wind speed (16), data were broken up into two parts by wind speed (WS): WS < 1.0 (m/s) and WS > 1.0 (m/s), in order to evaluate the model performances in various wind condition. Figure 7 showed comparative performances of models under varied wind condition, and performance measures were tabulated in Table 3. Compared with the other figures, Figure 7c seems to perform worse. For PM$_{2.5}$, CAL3QHC and CALINE4 have similar NMSE and $d$ value in all wind speed condition. There is also no significant difference between CAL3QHC and CALINE4 for the AB, FB, and RMSE results. For CO, CAL3QHC has high AB and FB for low wind speeds (WS < 1.0) than for high wind speeds and CALINE4 also has similar pattern. The NMSE and RMSE results of CAL3QHC and CALINE4 are also lower in high wind speed condition. Moreover, the $d$ value of CAL3QHC and CALINE4 are higher in low speed condition.

According to two classes of wind speeds, the performance measures indicate that CAL3QHC and CALINE4 have similar good predictions for PM$_{2.5}$ concentration. Conversely, for CO, CAL3QHC and CALINE4 failed to predict well, and when wind speed is over 1m/s, the performances of both CAL3QHC and CALINE4 improve significantly.
FIGURE 7 Comparative performances of models for PM$_{2.5}$ concentrations under varied wind condition. (a) PM$_{2.5}$ concentrations (WS < 1.0 m/s) (b) PM$_{2.5}$ concentrations (WS > 1.0 m/s) (c) CO concentrations (WS < 1.0 m/s) (d) CO concentrations (WS > 1.0 m/s).

Table 3 Performance measures under varied wind condition

<table>
<thead>
<tr>
<th>Parameters</th>
<th>PM$_{2.5}$ (μg/m$^3$)</th>
<th>CO (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>WS &lt; 1.0</td>
<td>WS &gt; 1.0</td>
</tr>
<tr>
<td>Absolute bias (AB)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CAL3QHC</td>
<td>-1.83</td>
<td>-3.02</td>
</tr>
<tr>
<td>CALINE4</td>
<td>0.60</td>
<td>-1.80</td>
</tr>
<tr>
<td>Fractional bias (FB)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CAL3QHC</td>
<td>-0.03</td>
<td>-0.05</td>
</tr>
<tr>
<td>CALINE4</td>
<td>0.01</td>
<td>-0.03</td>
</tr>
<tr>
<td>Root mean square error (RMSE)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CAL3QHC</td>
<td>4.10</td>
<td>5.07</td>
</tr>
<tr>
<td>CALINE4</td>
<td>4.92</td>
<td>4.64</td>
</tr>
<tr>
<td>Normalized mean square error (NMSE)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CAL3QHC</td>
<td>0.01</td>
<td>0.01</td>
</tr>
<tr>
<td>CALINE4</td>
<td>0.01</td>
<td>0.01</td>
</tr>
<tr>
<td>Index of agreement (d)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CAL3QHC</td>
<td>0.99</td>
<td>0.97</td>
</tr>
<tr>
<td>CALINE4</td>
<td>0.98</td>
<td>0.98</td>
</tr>
</tbody>
</table>

5. CONCLUSIONS

This study shows that CAL3QHC perform well in estimation for both PM$_{2.5}$ and CO concentrations at a road intersection at 5-min scale in Shanghai, while the performance of CALINE4 is not good for CO. Generally, CAL3QHC performs better than CALINE4 for both PM$_{2.5}$ and CO, with the index of agreement of 0.98 and 0.51, respectively. While CALINE4 has a smaller fractional bias of 0.01 for PM$_{2.5}$. 
As for model performances in varied locations and time periods, there is no significant
difference among varied locations. For both PM$_{2.5}$ and CO, CAL3QHC and CALINE4 perform
better at noon (i.e. off-peak period), while the performances at morning and evening peak are
similar, which may be relative to the fluctuation of traffic volume.

For both models, the performances for PM$_{2.5}$ estimation do not change a lot for different
wind speed classes. However, for CO, the performances of CAL3QHC and CALINE4 when
wind speed under 1m/s are obviously worse than the results of the opposite condition, which
indicates that the models may be more sensitive for wind speed in CO estimation case.

This study presents a successful try of short-term estimation at intersection by using line
source dispersion models. However, as the field measurements are limited in particular area
and season, the performances of mentioned models for short-term estimation have not totally
certified. Monitoring campaign in varied areas and seasons are required for further study.

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