Supplementary material for

Ground vibrations recorded by fiber-optic cables reveal traffic response to COVID-19 lockdown measures in Pasadena, California

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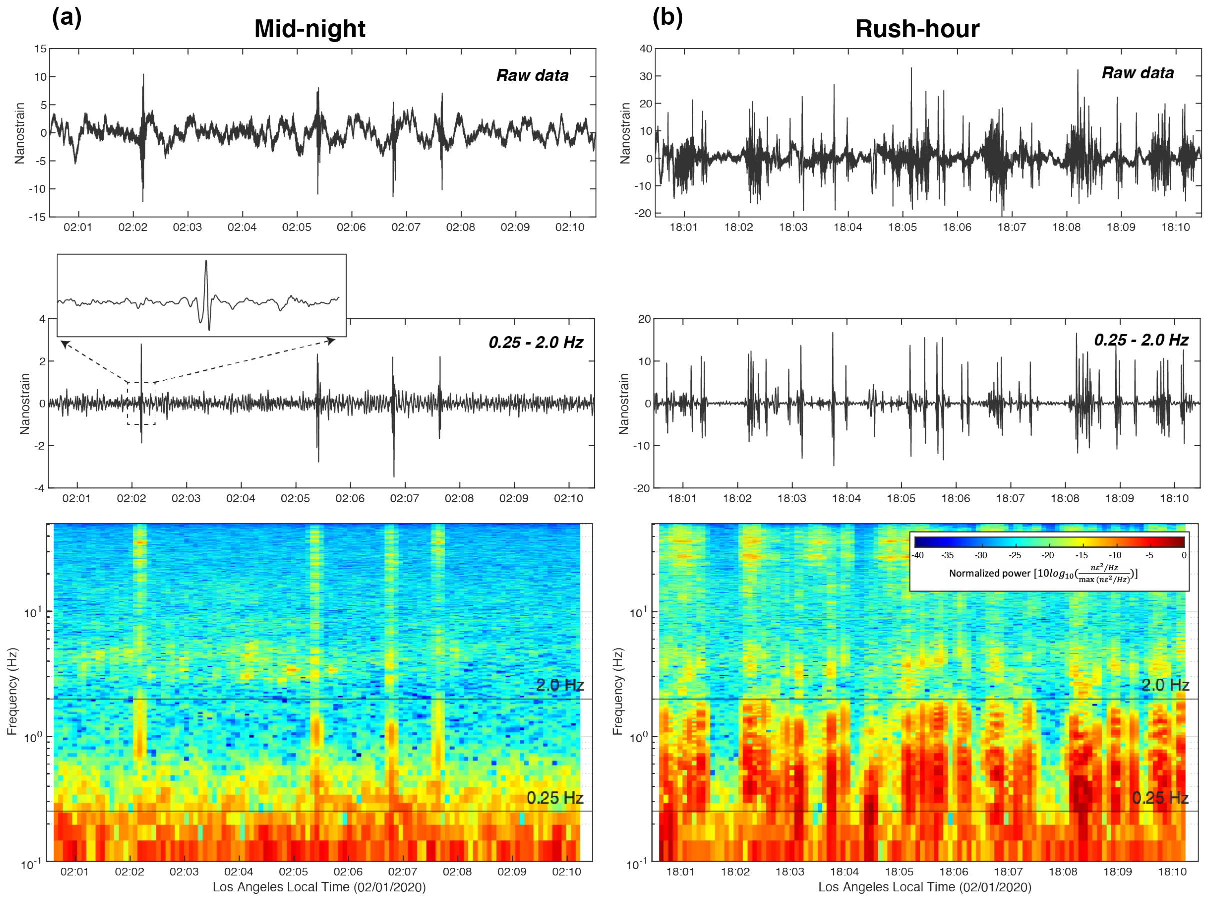

Figure S1. Time-frequency analysis for one of the DAS channels located on the arterial street in Pasadena. From top to bottom shows the raw data, the band-pass filtered data (0.25-2.0 Hz), and the spectrogram. We use the filtered data for vehicle identification, as spectrogram analysis shows clear traffic signals within these frequency bands. (a) and (b) for mid-night and rush hour, respectively.

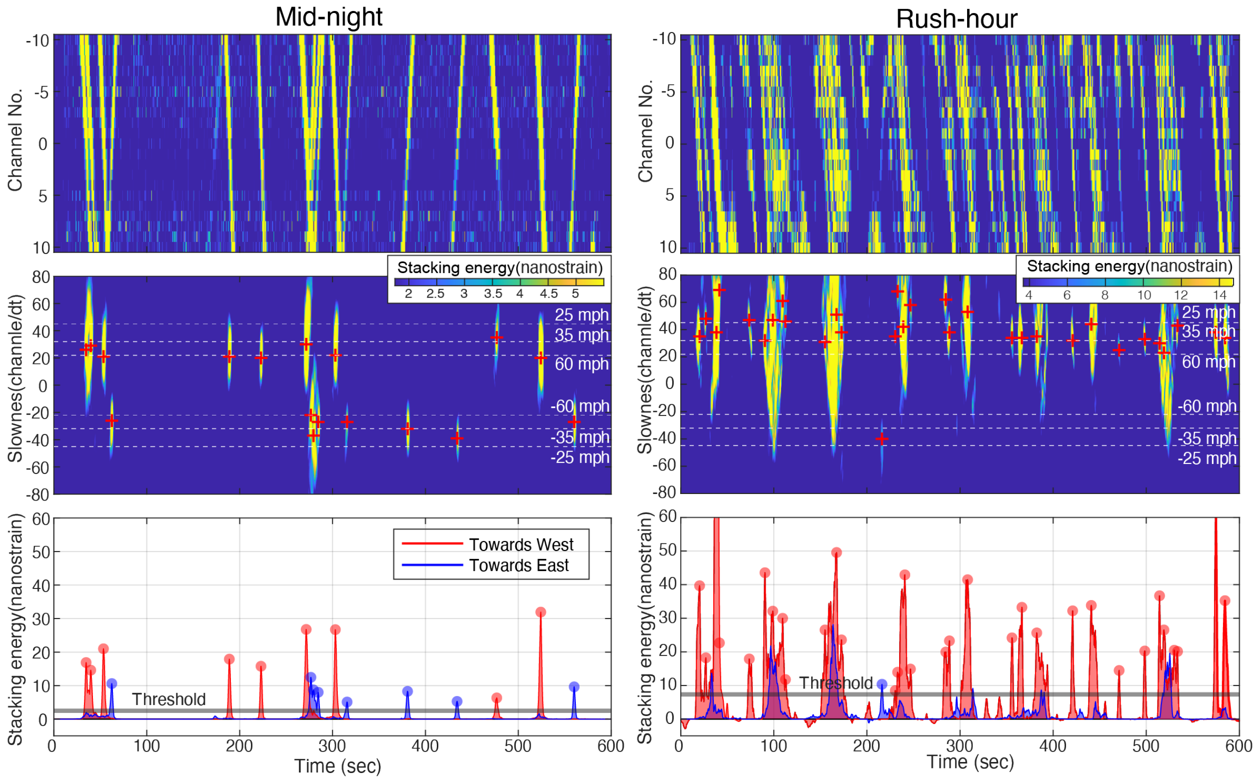

Figure S2. Examples of traffic stream parameter estimation during mid-night and rush hour for one of the subarrays located on an arterial street in Pasadena (E. Colorado Blvd., Fig. 1 shown in main text). From the top to the bottom shows the DAS records (0.25 – 2.0 Hz), the vespagram from 4th-root slant-stacking, and the 1-D stacking energy profile integrated from 2-D vespagram. For traffic mean speed estimation, we use local maxima analysis to find the peaks (red crosses) in the 2-D vespagram to calculate the mean speed per 10 mins. For traffic volume estimation, we use the duration of the signal over the threshold level to estimate the traffic volume per 10 mins, as the local maxima analysis tends to underestimate the traffic volume if vehicles are passing in close proximity.

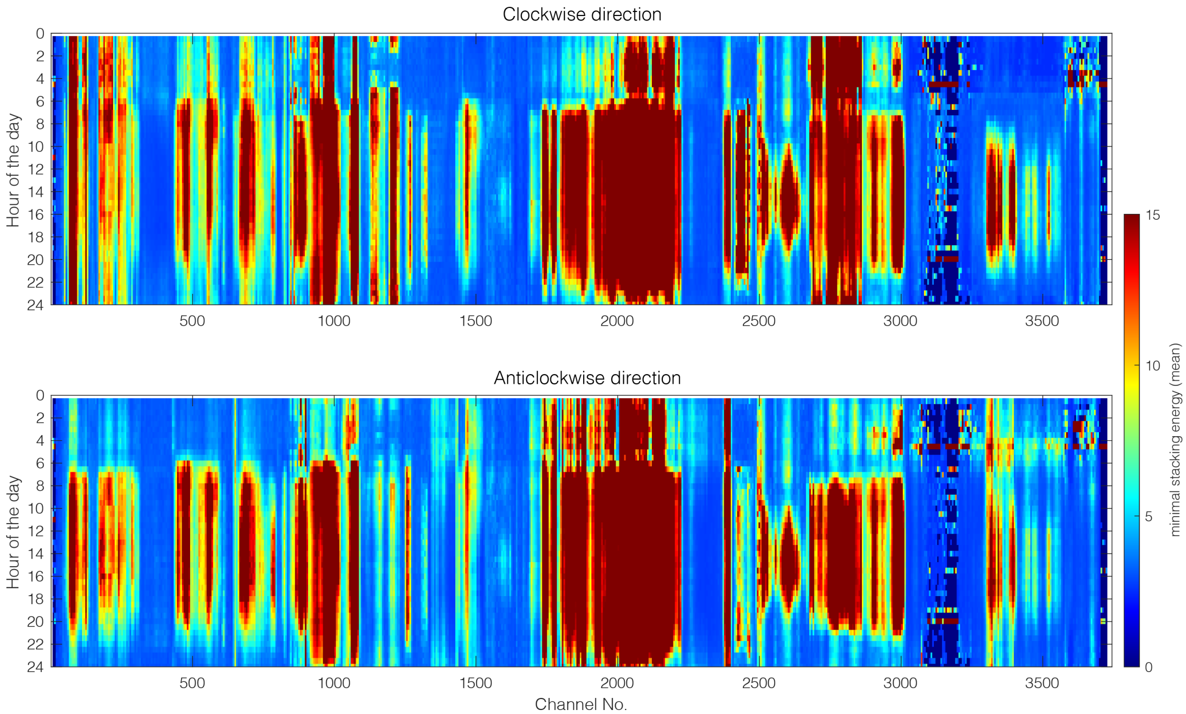

Figure S3. The dynamic threshold values (median value of the minimal identified peaks from the local maxima analysis) used in signal-duration based analysis. The threshold values vary with time and location because of the varying noise level and different road situations (e.g., the coupling condition, local velocity structures, the distance from the fiber to the road).

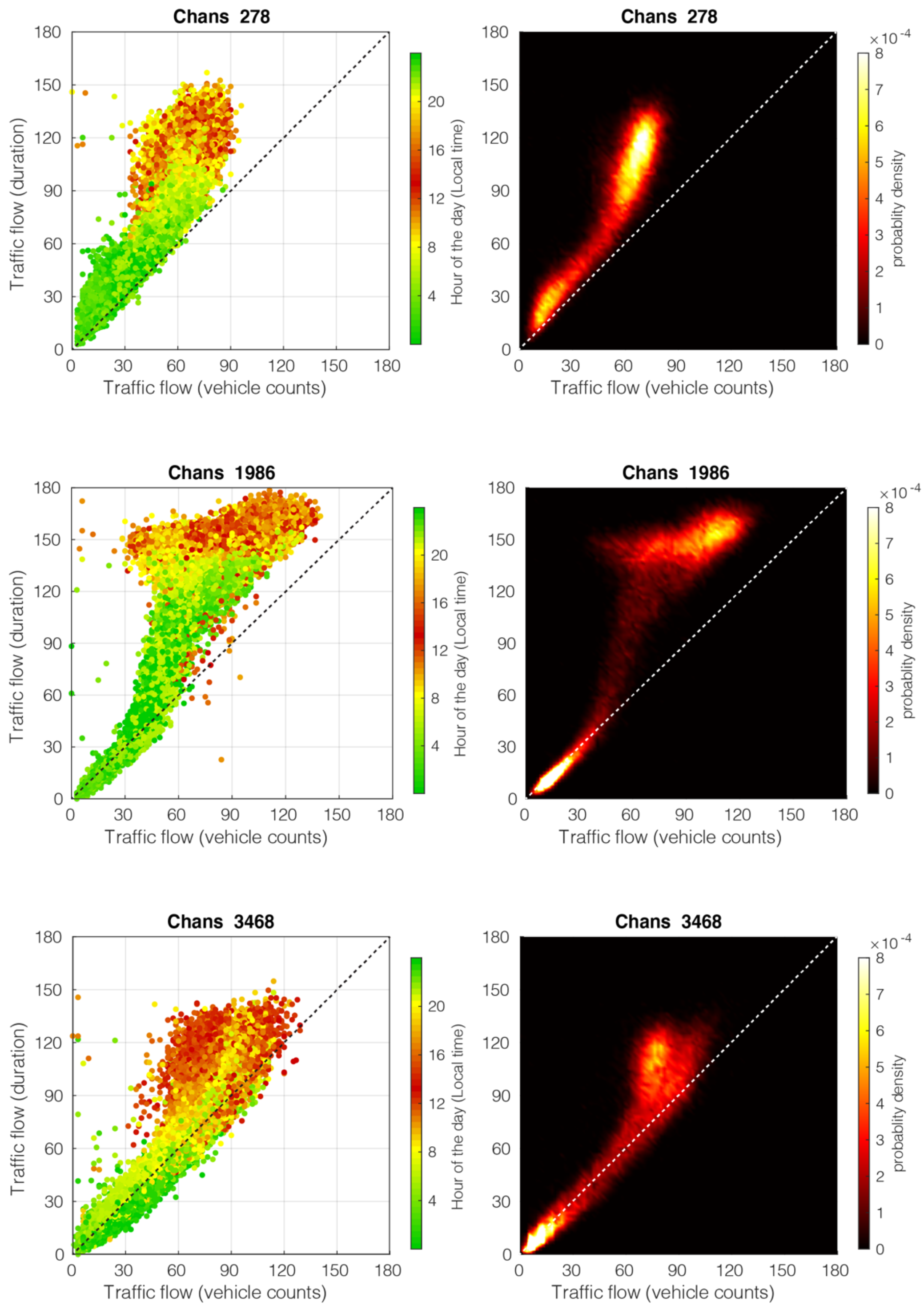

Figure S4. Comparison between the local maxima analysis and the signal-duration based analysis. The left column shows the scattered plots, with the color represents the hour of the day. The right column shows the probability density plots, with a warmer color represents a higher probability. Two methods produced similar traffic volume estimates when there are fewer vehicles on the road. However, during the rush hour (red circles shown in the left column), the signal-duration based method can better resolve the traffic volume, as verified by comparing with the real traffic counts data from the Department of Transportation, Pasadena (shown in Figs. S6-S7).

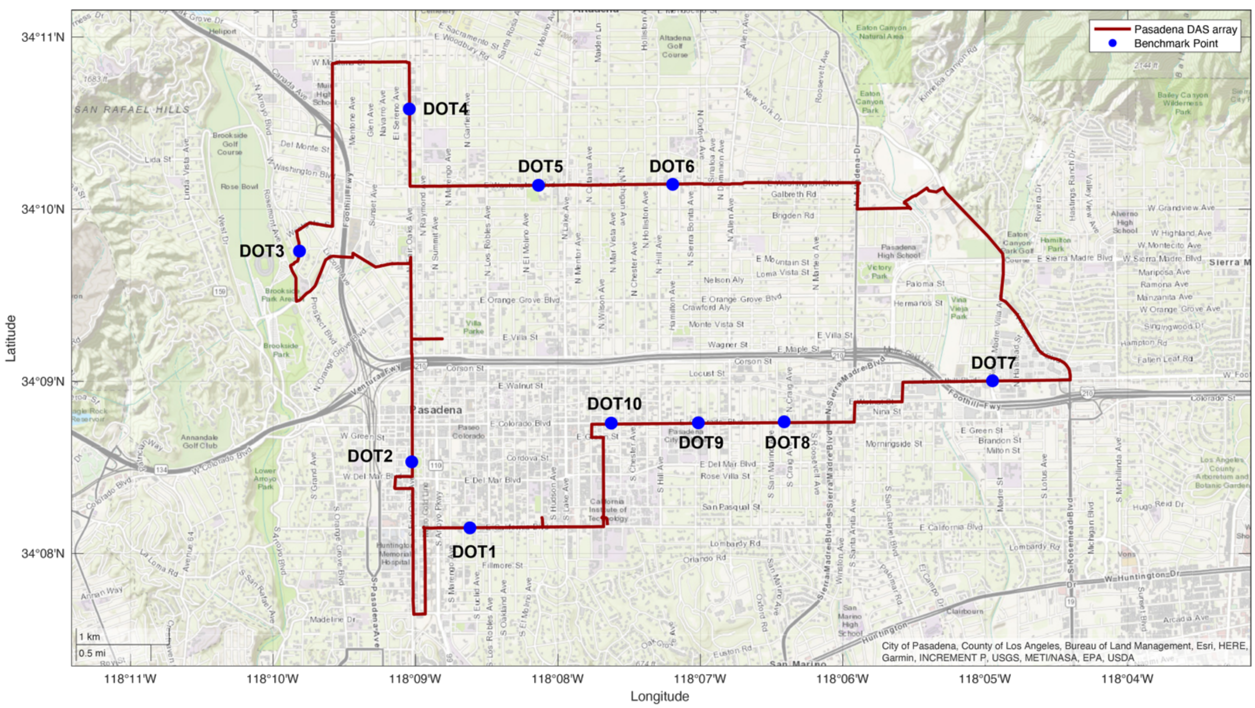

Figure S5. The map shows the Pasadena DAS array (red line) and the selected points for benchmark (blue circles, with results shown in see Figs. S5-S6). We select these points as there are real traffic volume counts data from the Department of Transportation, Pasadena (https://www.cityofpasadena.net/transportation/traffic-engineering-operations/#traffic-volumes).

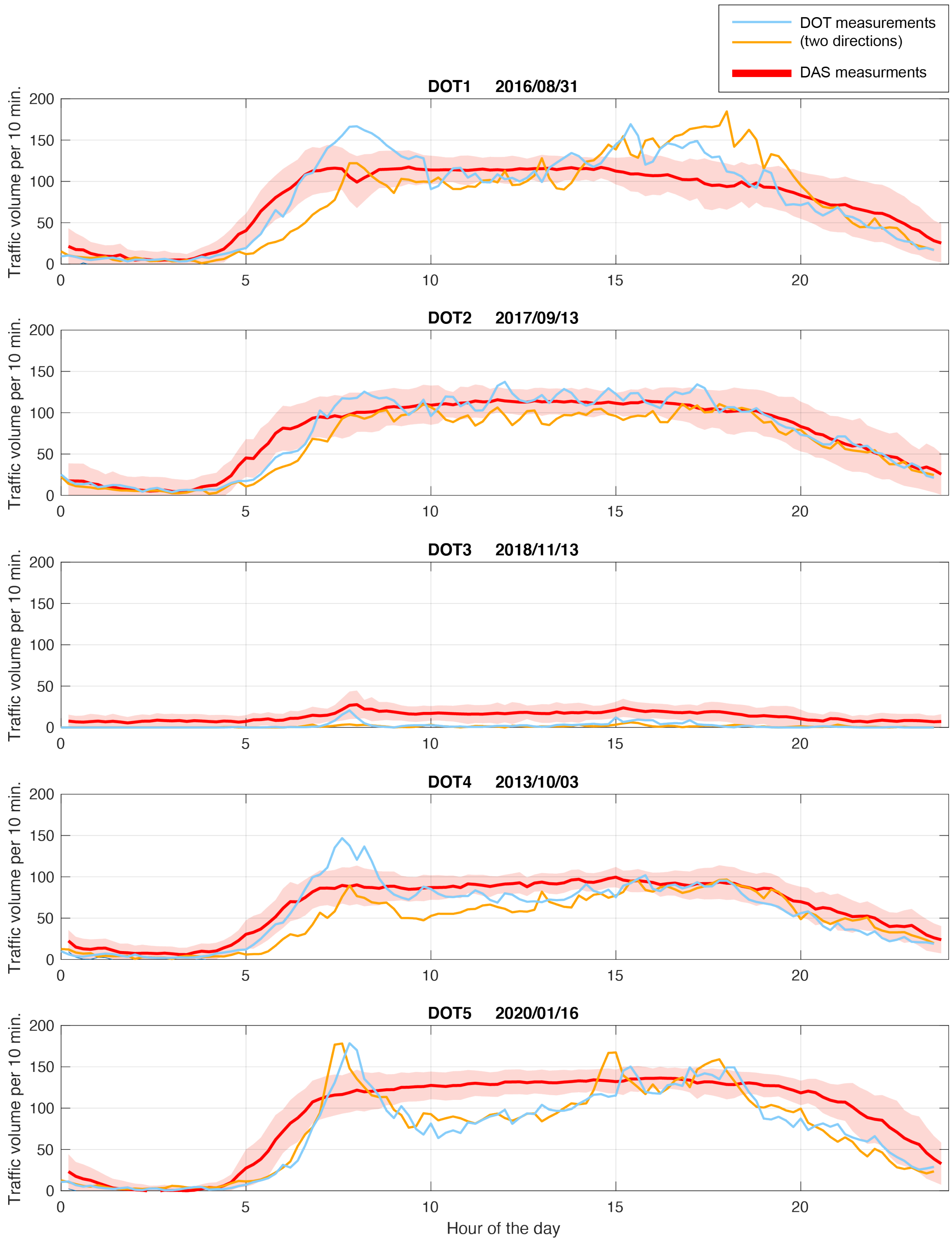

Figure S6. Comparison of traffic volume estimation between our study and that from the Department of Transportation (DOT), Pasadena (locations 1-5, see Figure S5). The DOT dataset contains single-day high-accuracy traffic volume measurement. For comparison, we calculate the mean diurnal (working days) traffic volume using all the days before the COVID-19. The vehicle numbers estimated from our method are in good agreement with the real traffic counts data from the DOT, though resolving the exact traffic volume using DAS is quite challenging due to the limitations of dark fiber installations (e.g., coupling, cable position, the multi-lane road against a single road-side fiber).

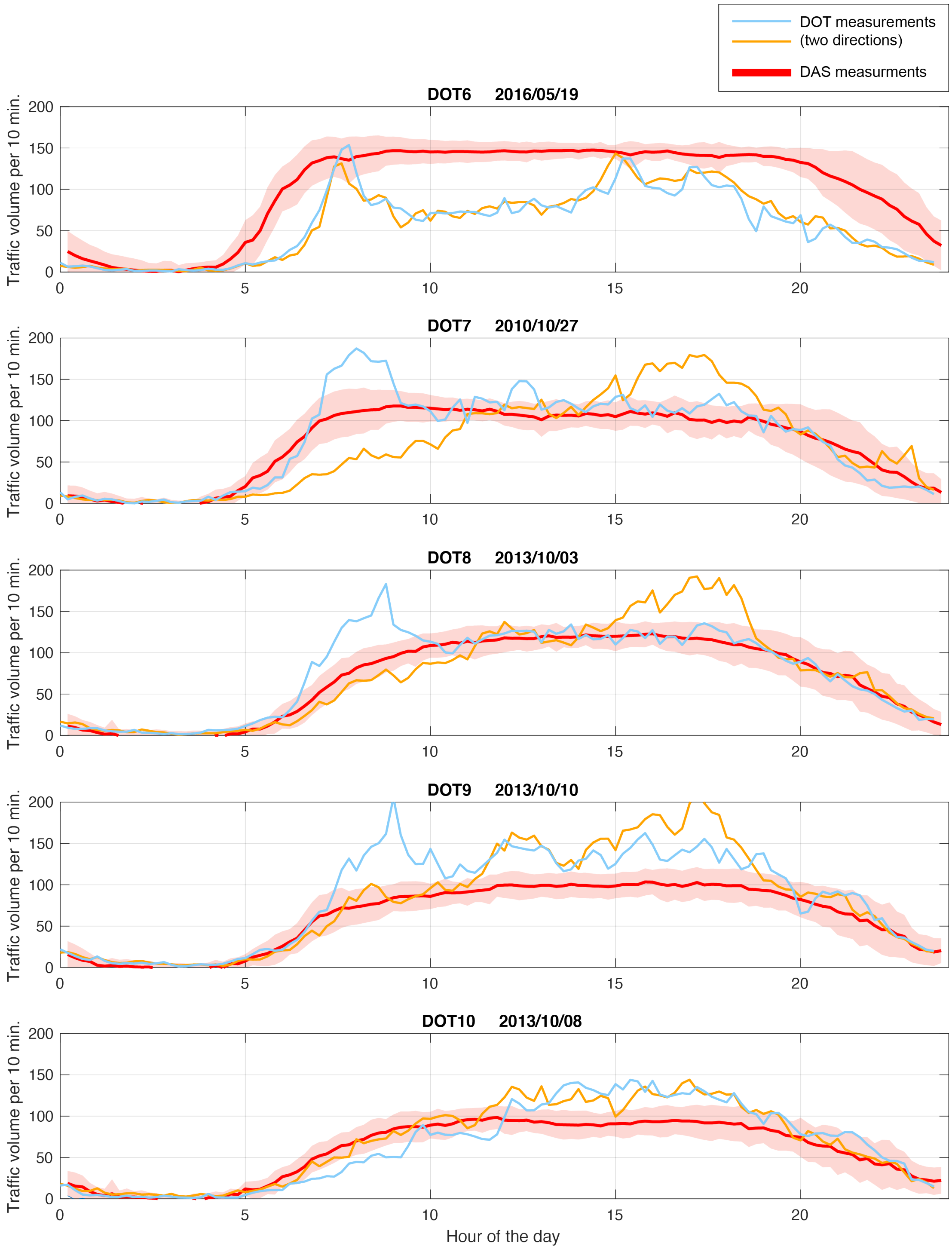

Figure S7. Same to Figure S6, but for locations 6–10.

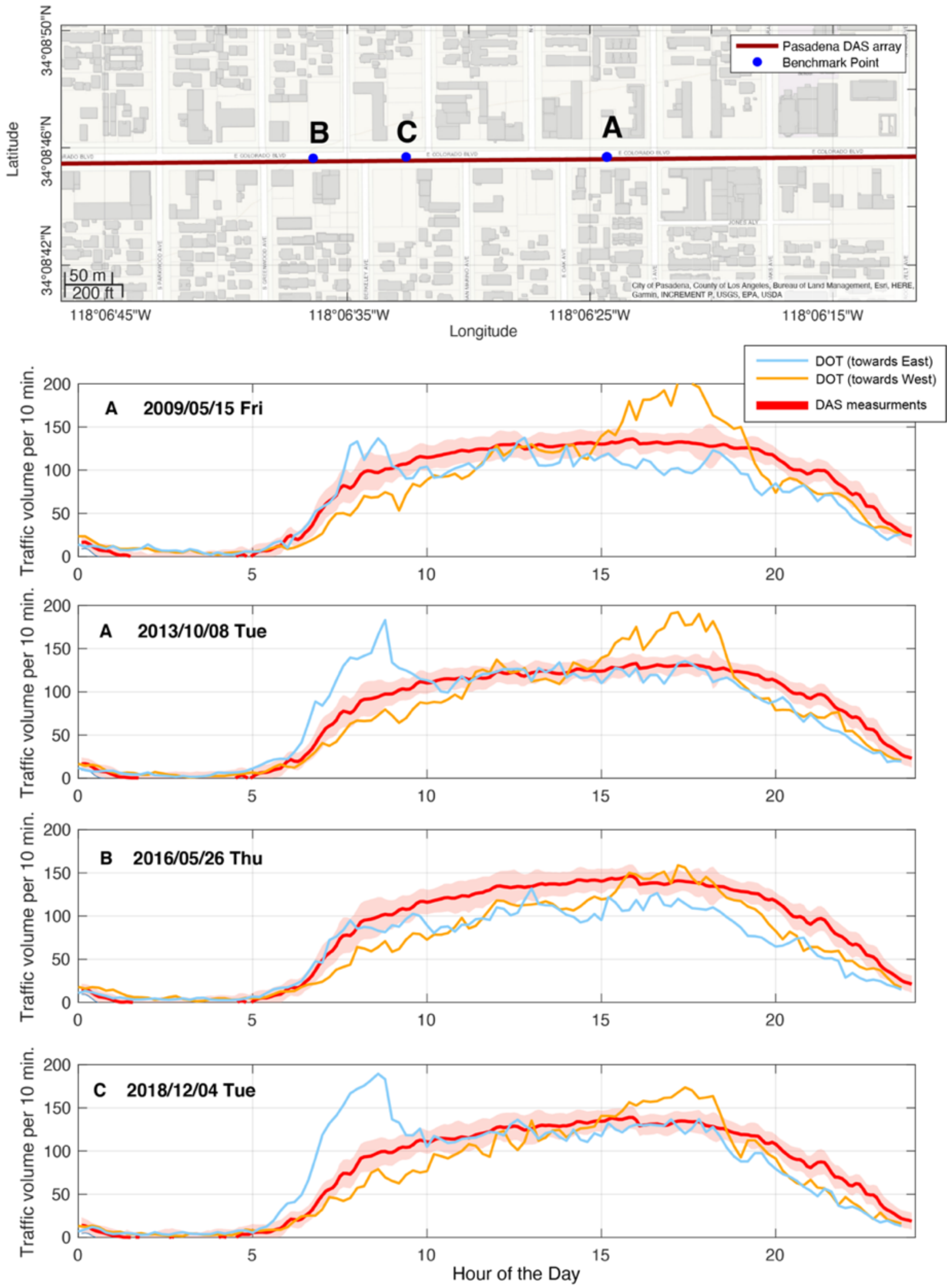

Figure S8. Comparison of DOT traffic volume measurements made at nearby locations (within ~200 m), but in different dates (from 2009 to 2018). The averaged statistical daily traffic volumes estimated by our study are shown as red lines for comparison. The variation of traffic volume measurements in nearby locations could be to the long-term and/or short-term variation.

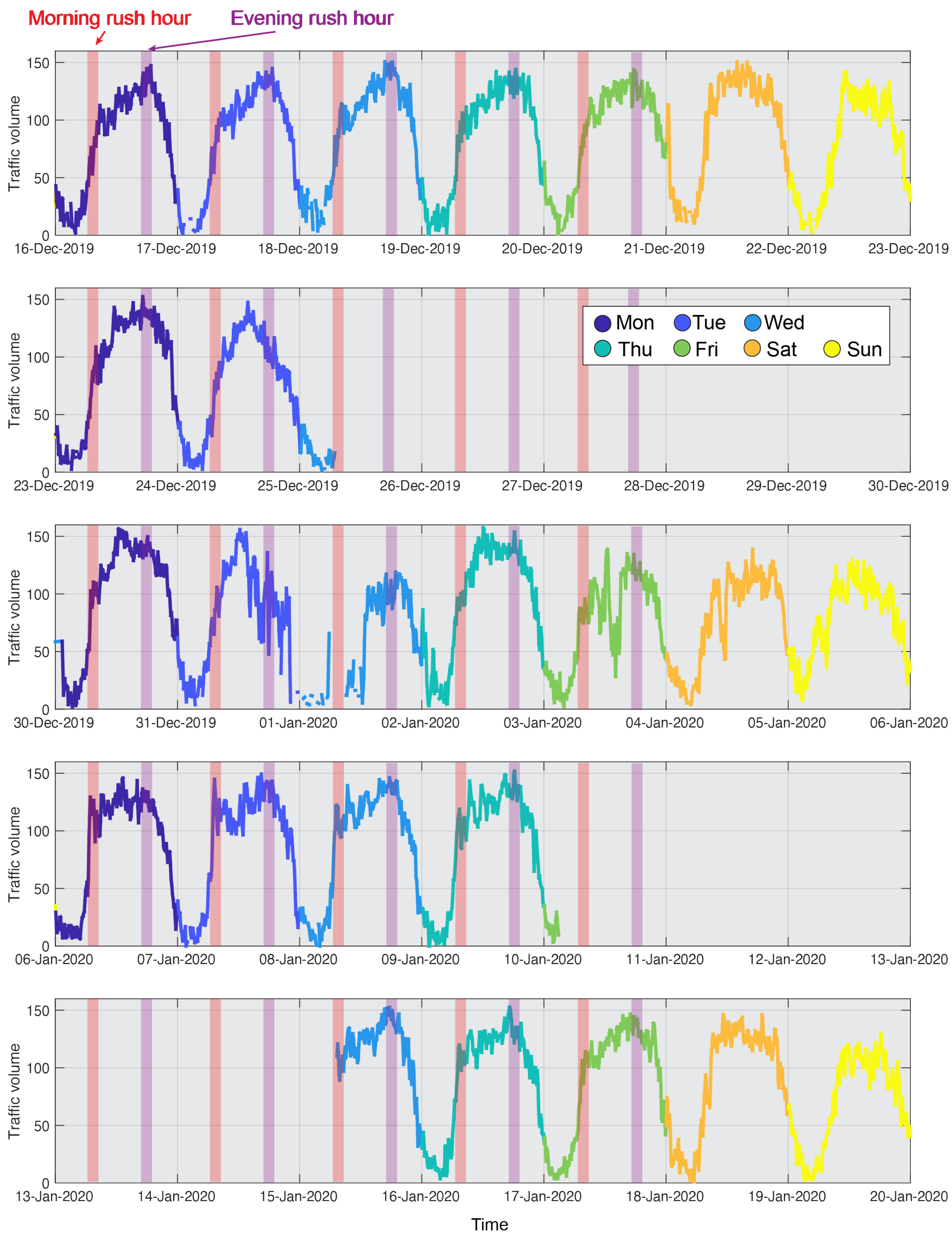

Figure S9. Traffic volume measurements conducted by DAS at a single fiber location (located near the DOT9 shown in Fig. S7), but in different dates. We can see an overall similar traffic trend in different dates, but there is significant day-to-day variation (even if we only consider working days). Stacking these data tends to eliminate the morning and evening rush hours.

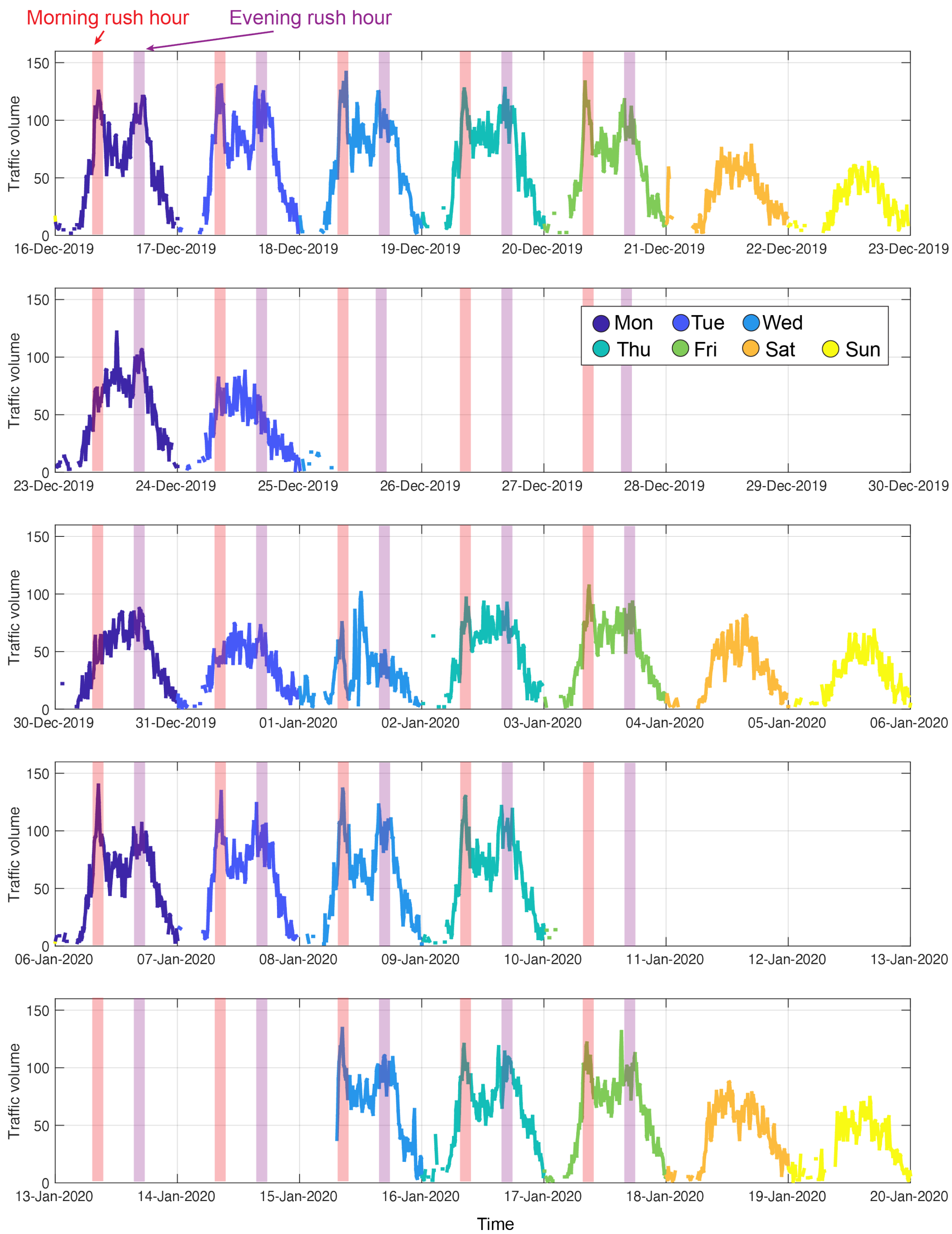

Figure S10. Same to Figure S9, but for a channel located near the Caltech.