Detectable Weekly Cycle of Urban CO_2 Emissions from Satellite Observations: A Case Study in Los Angeles

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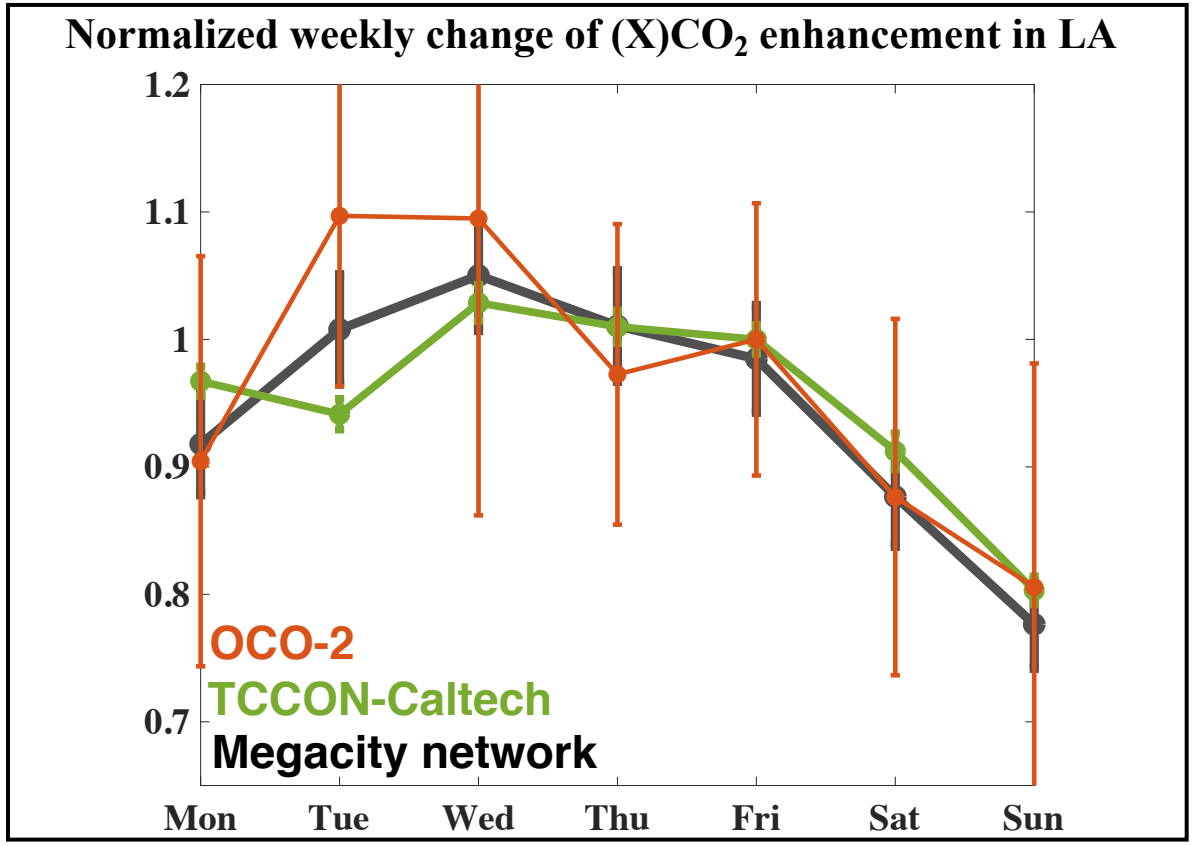

IWGGMS 18
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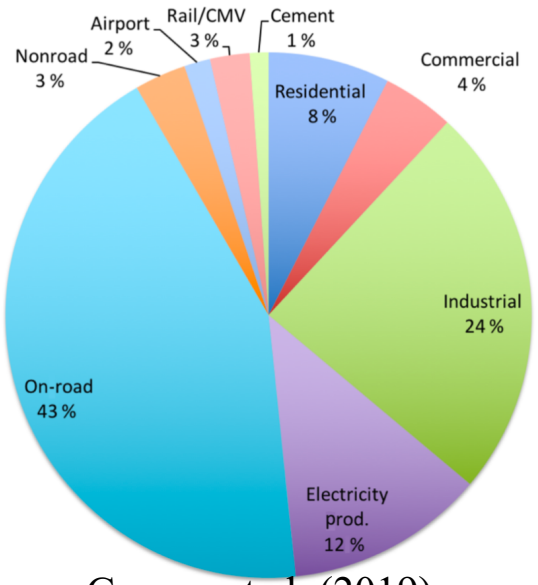
Weekly cycles of on-road traffic volume in Los Angeles

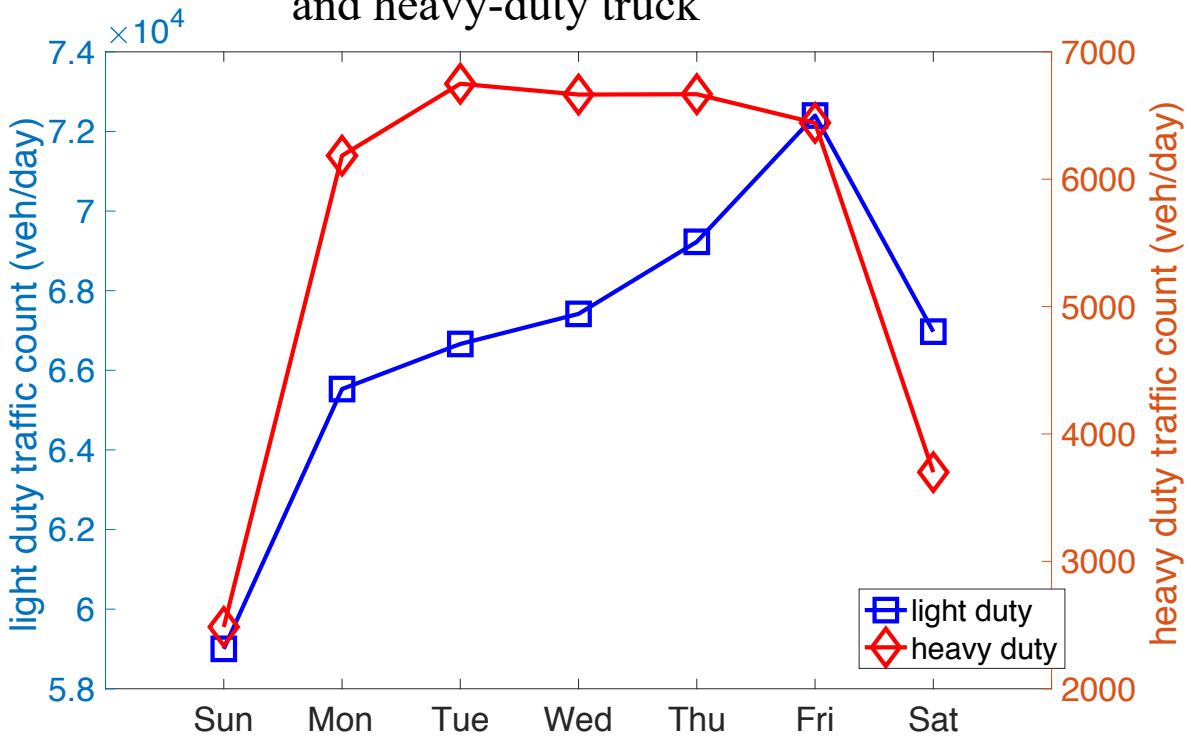
- The LA megacity (South Coast Air Basin) has a population of ~15M;
- The largest urban carbon emitter among all US cities (Moran et al., 2018).
- $FFCO_2$ emission proportions by sector from Hestia (Gurney et al., 2019), On-road traffic is close to a half.



Gurney et al. (2019)

PEMS traffic sensor network: dense detectors on major highways that collect real-time traffic information.

Traffic counts for light-duty cars and heavy-duty truck

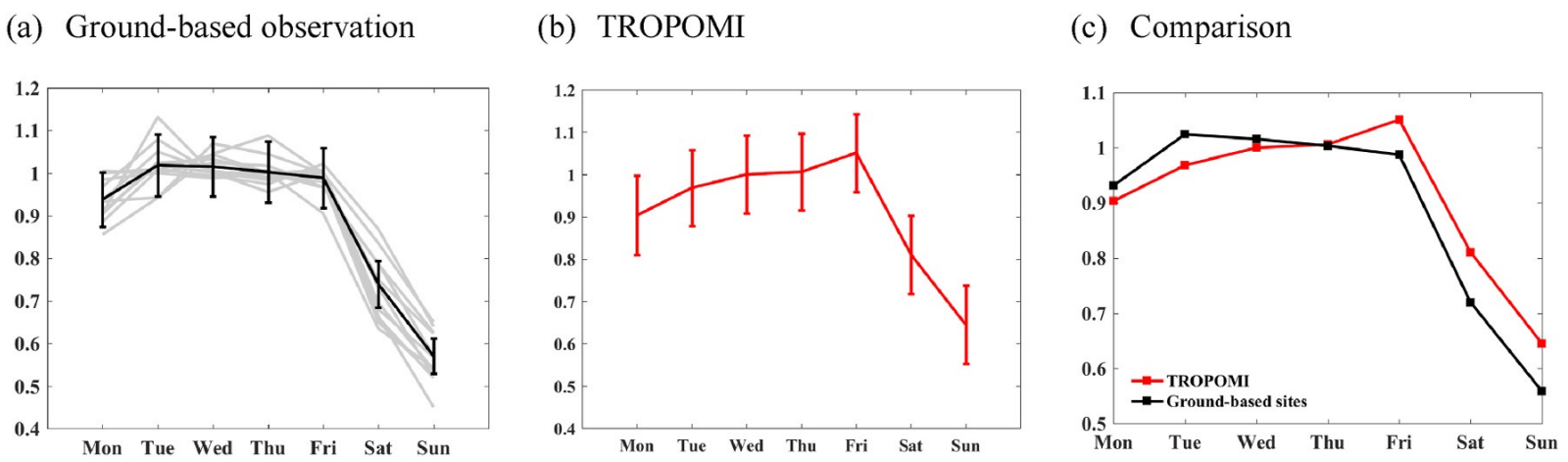


- Sunday drop: cars 20%; trucks 60% compared to weekly average;
- The data are collected from PEMS weigh-in-motion sensors from 2010 to 2016 in the counties of Los Angeles, San Bernardino/Riverside, and Orange.

Weekly cycles of NO_2 from ground-based and satellite data (No surprise!)

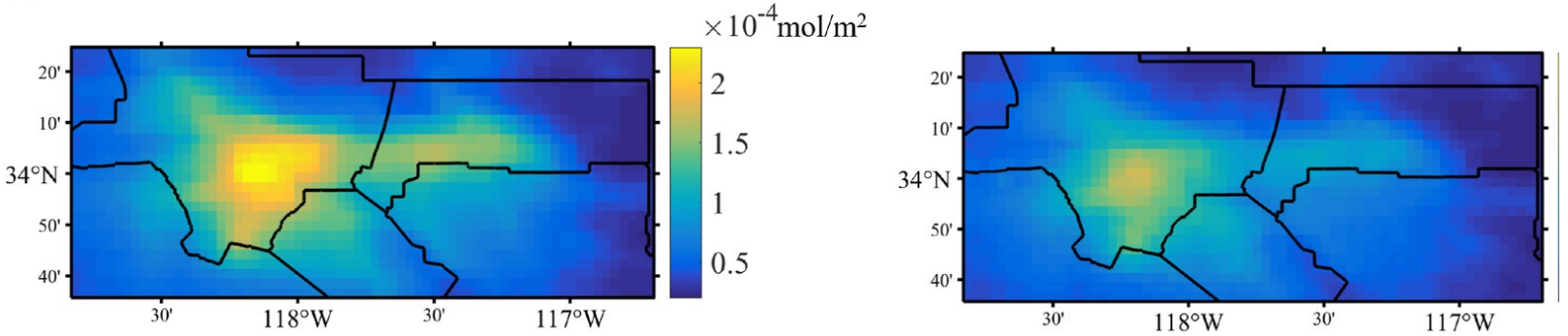
- Anthropogenic NO_2 emissions in cities are highly detectable due to its short lifetime (has been reported in many previous papers)
- We use normalized weekly change in order to compare results from ground-based and satellite observations.
- Consistent weekend decline from both ground-based and satellite observations
- The weekday-weekend effect can also be clearly seen by TROPOMI.

Normalized weekly change (weekday median=1)



The NO2 weekly cycles, which has been normalized by the weekday median, from (a) ground-based observations from 2018 to 2019 (12:00pm-3:00pm) from SoCAB air quality monitoring sites; and (b) TROPOMI NO2 columns from 2018 to 2019. (c) The comparison of weekly cycles from (a) and (b).

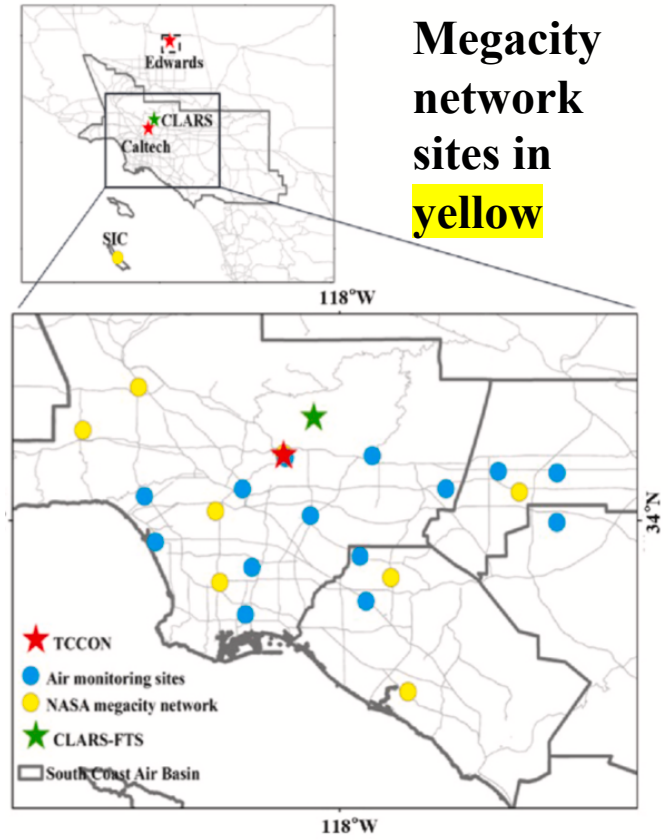
Spatial maps



Mean tropospheric NO_2 vertical column densities from TROPOMI for 2018-2019 on weekdays (left) and Sundays (right)

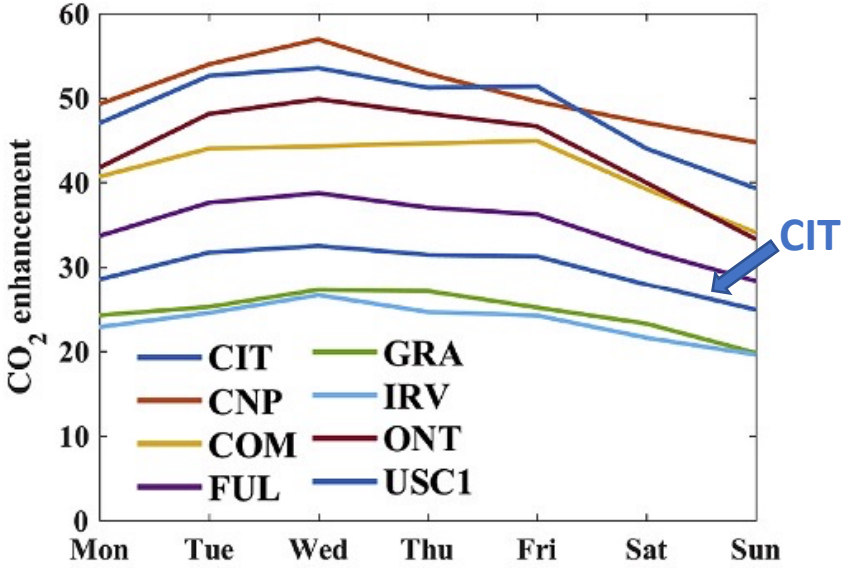
Weekly cycles of CO_2 enhancement from ground-based observations

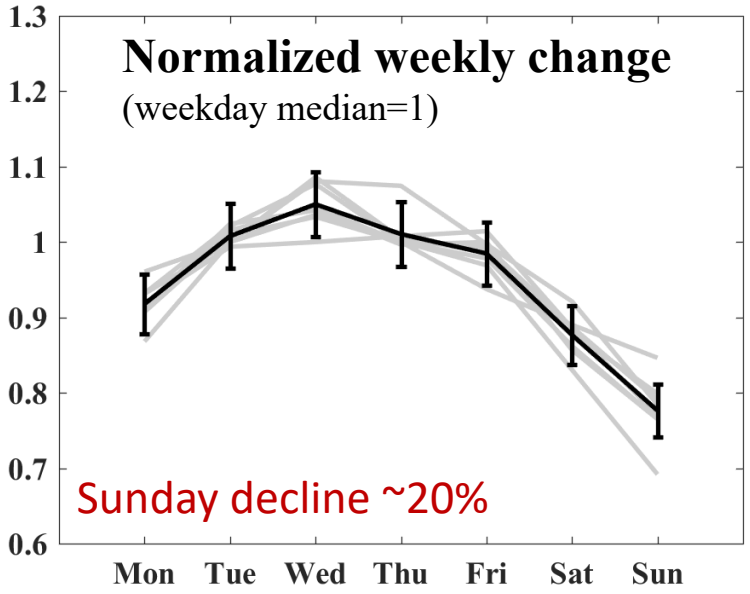
- We collect in-situ CO2 data from NASA megacity network in LA (2005-2009)
- Following Verhulst et al. (2017), use San Clemente Island (SCI) as the background site and do data screening.
- We see consistent weekly change of CO_2 enhancement (~20%; 5-10ppm)
- For Caltech site, the Sunday drop is **6ppm**. (An rough estimate) If we assume it is uniform in the PBL, which accounts for 1/10 of total column, then the weekly cycle in XCO_2 may be around **0.6ppm**. This maybe the **upper bound** because the in-situ data are close to surface layer.
- As I will show later, this is not far away from estimates using XCO_2 from TCCON (~0.25ppm) and OCO-2 (~0.3ppm).



NASA Megacity network sites in yellow

(from 12:00pm to 3:00pm, 2015-2019)

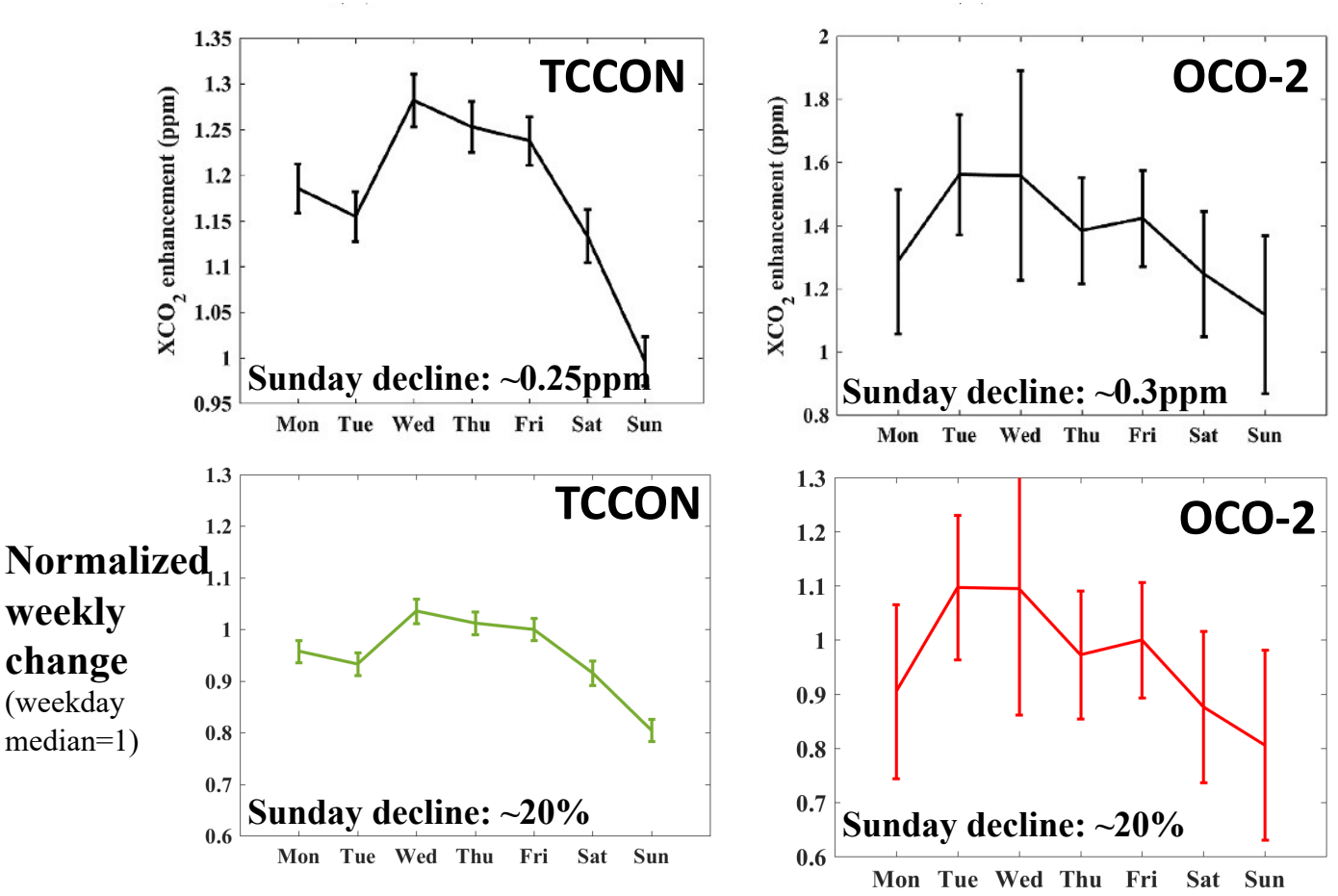




Weekly cycles of XCO_2 enhancement from TCCON and OCO-2

- We collected XCO2 data from TCCON and OCO-2 (v9r; 2014-2019). To compute the XCO2 enhancement, we selected the Edwards site as the background.
- Following Hedelius et al. (2018), we corrected the bias caused by the elevation difference between Edward (0.7km) and Caltech (0.23km).
- Differences due to averaging kernel are not corrected because it will not affect our weekly cycle analysis.
- For TCCON, we only use data between 12:00pm to 3:00 pm to match the satellite overpass time.
- For OCO-2, we have about 130 days of good observations (>30/day) in total (including about 30 days of target mode observations). We use only half of them that have corresponding background observations.
- #Obs for each days: Mon(6), Tue(9), Wed(12), Thu(8), Fri(9), Sat(8), Sun(9). We calculated the daily mean first and then the weekly mean.
- Error bars are computed based on the retrieval errors (in the data product) and error propagation.

TCCON-Caltech (12:00am to 3:00 p.m., 2014–2019) ;OCO-2 observations (2014–2019)



Weekly cycle is clear; Similar decline from both datasets;
Larger OCO-2 error bar due to a smaller amount of data.

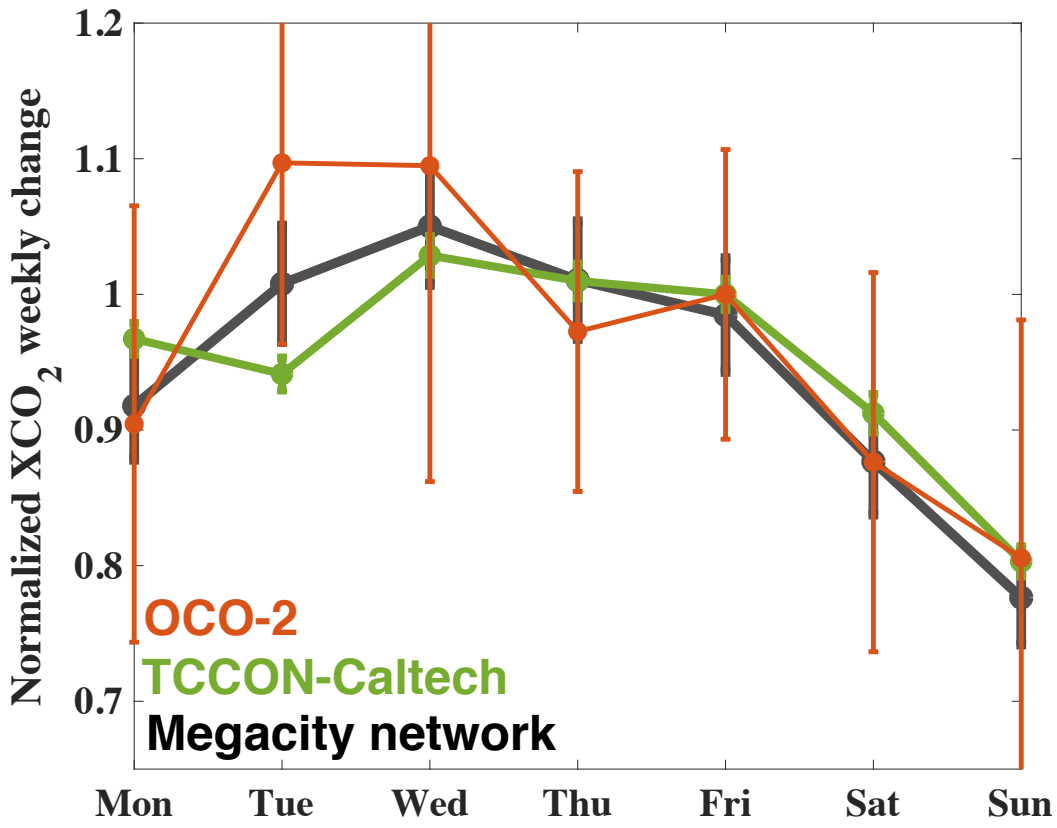
Weekly cycle of LA's urban CO_2 emissions is directly detectable from space

Conclusions:

- The weekly cycles of traffic volume and strong weekly cycle of NO_2 from ground-based and satellite observations;
- Consistent weekly patterns of CO_2 or XCO_2 enhancement (approximately proportional to urban $FFCO_2$ emissions) in LA observed by Megacity network, TCCON, and OCO-2. The Sunday decline is about 20%;
- This observed weekly cycle may be useful for calibrating the bottom-up $FFCO_2$ that is being used to drive the CO_2 model simulations.

Discussions:

- To apply the method to other megacities, the megacity should have enough days of good measurements across the week (to beat down the noise); an appropriate background site needs to be selected.



The CO2 or XCO_2 enhancement weekly cycles, normalized to the weekday median values

Data acknowledgements:

- The XCO_2 observations from **OCO-2 team** are publicly available at https://disc.gsfc.nasa.gov/datasets/OCO2_L2_Lite_FP_9r
- The **NASA Megacities Carbon Project** for providing the ground-based CO_2 observations, Available at https://data.nist. gov/od/id/mds2-2388. The data collected by the Megacities Carbon Network was partially funded by NIST's Greenhouse Gas Measurements Program.
- The **Total Carbon Column Observing Network** for providing the CO_2 data at https://tccondata.org/
- **California Air Resource Board** for providing the ground-based NO_2 observations, Available at https://www.arb.ca.gov/a qmis2/aqdselect.php,
- The tropospheric columns of NO_2 from **TROPOMI** were downloaded from Google Earth Engine (https://earthengine.google.com/).
- The traffic counts were download from **PEMS** (pems.dot.ca.gov) managed by CalTran.

Associated paper:

Wang, H., F.-Y. Gong, S. Newman, and Z.-C. Zeng* (2021), **Consistent weekly cycles of atmospheric NO_2, CO, and CO_2 in a North American megacity from ground-based, mountaintop, and satellite measurements**, *Atmospheric Environment*, https://doi.org/10.1016/j.atmosenv.2021.118809.

Backup slides

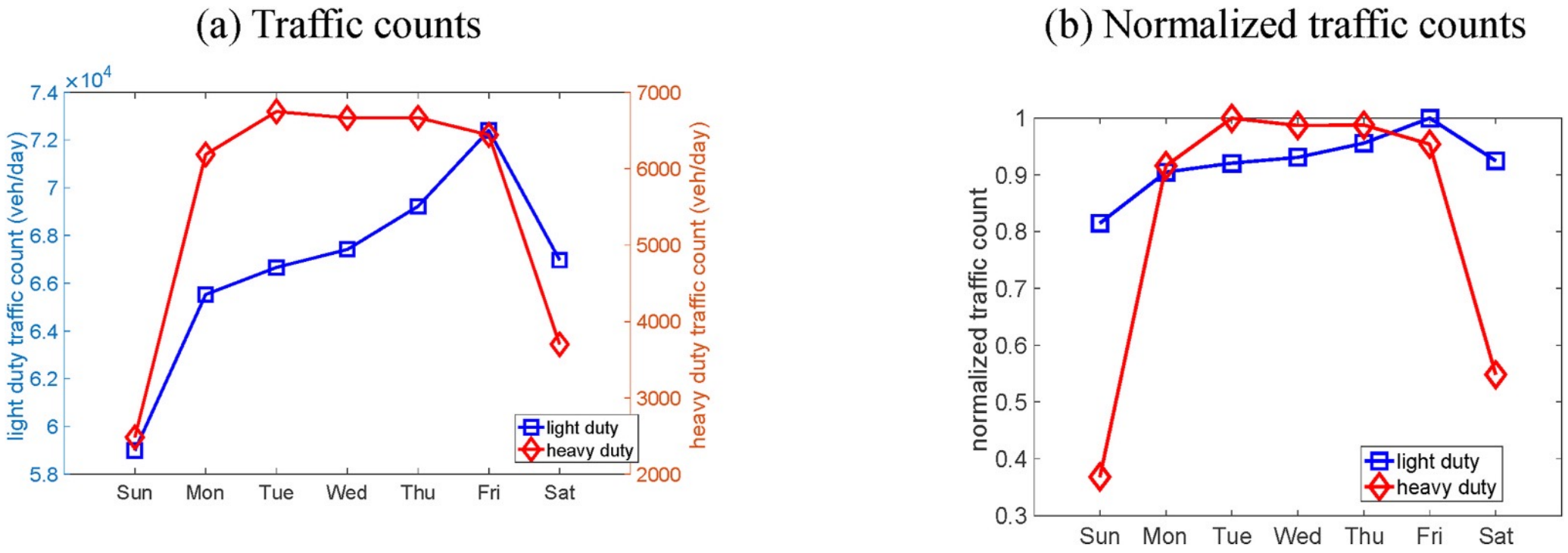
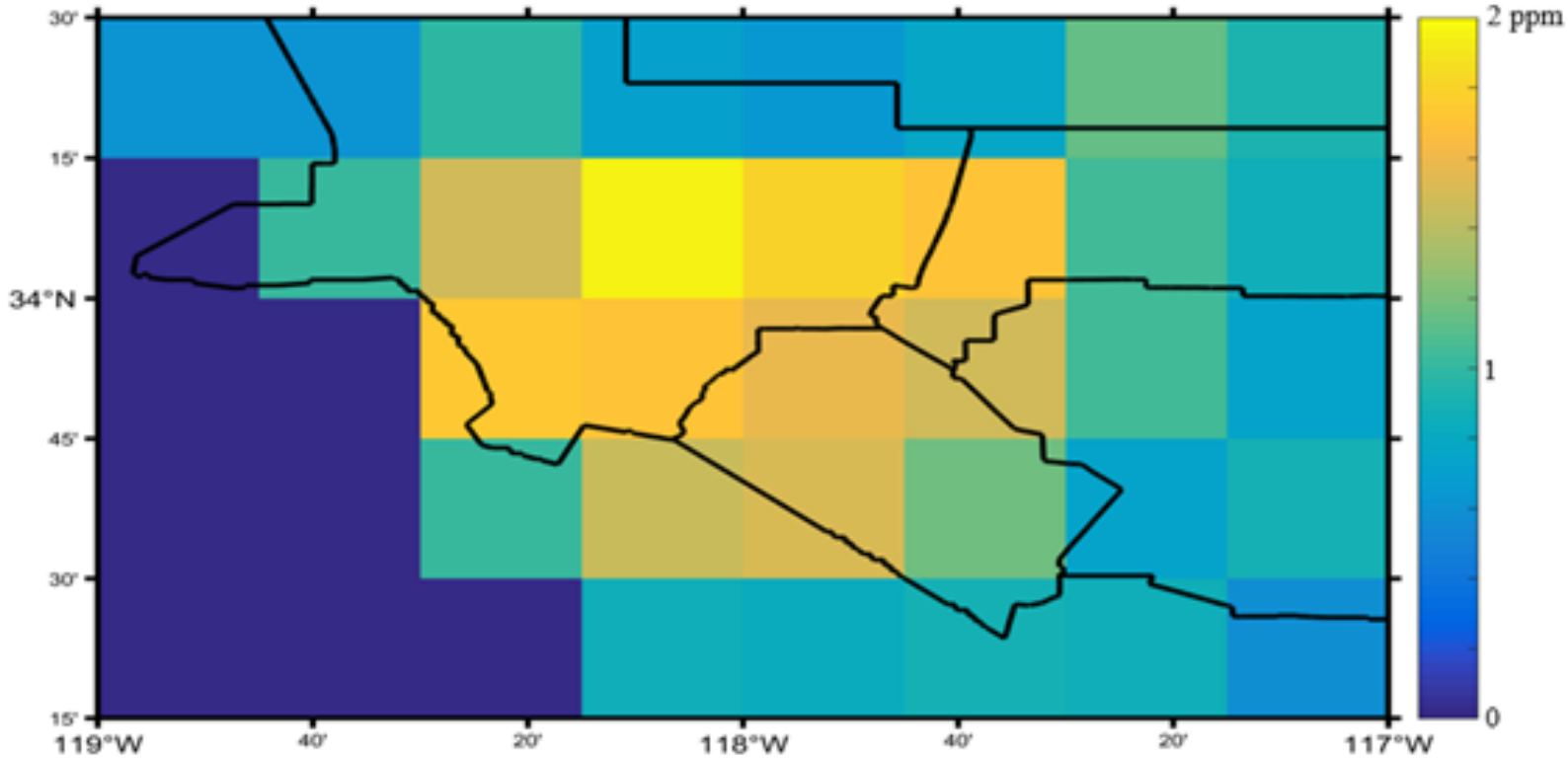


Fig. 2. (a) The traffic counts for light-duty cars and heavy-duty trucks; (b) the same as (a) but normalized by the highest weekday value. The data are collected from PEMS weigh-in-motion sensors from 2010 to 2016 in the counties of Los Angeles, San Bernardino/Riverside, and Orange. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)


30'
15'
34°N
45'
30'
15'
119°W
40'
20'
118°W
40'
20'
117°W
2 ppm
1
0

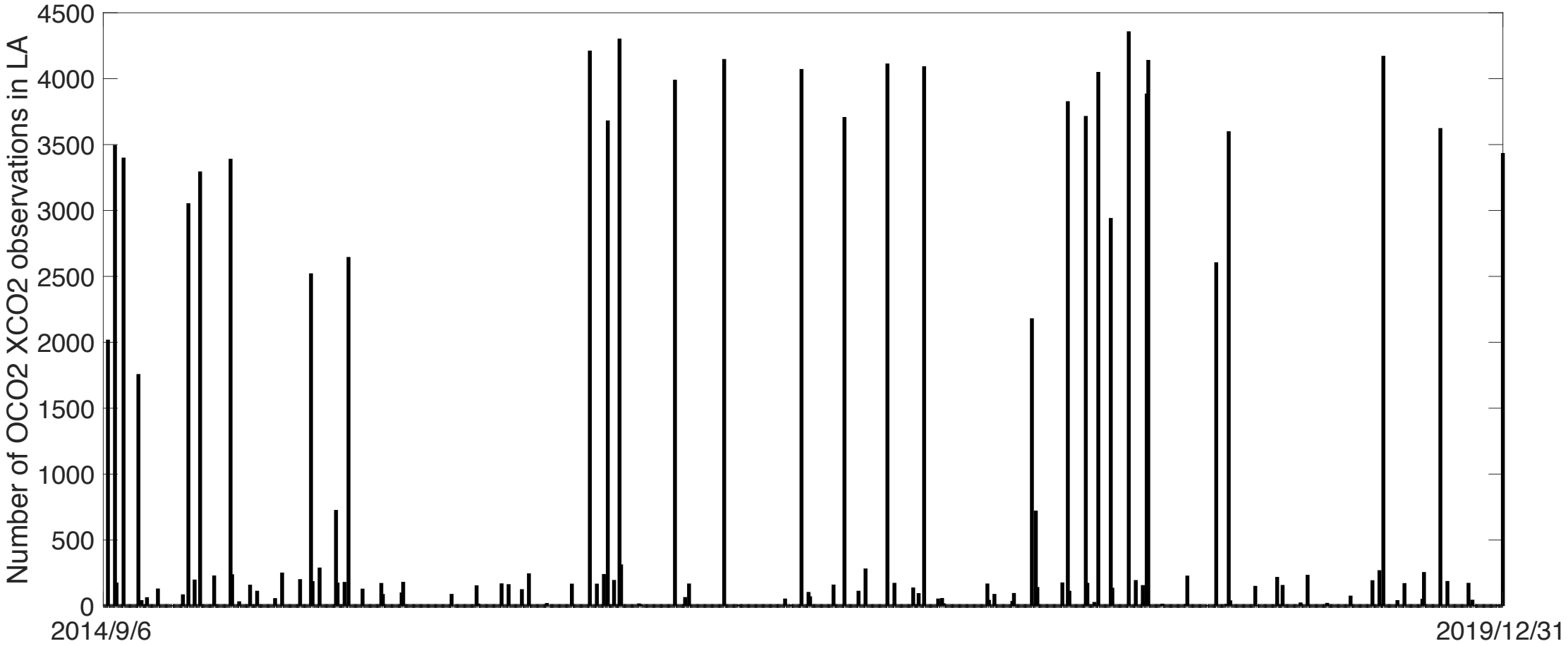

Number of OCO2 XCO2 observations in LA
4500
4000
3500
3000
2500
2000
1500
1000
500
0
2014/9/6
2019/12/31

Fig. A6. Examples of XCO2 observed from OCO-2 on weekday (left, 2014-09-12) and weekend (right, 2014-09-21).

The elevations for Caltech and Edwards are 0.23 km and 0.70 km, respectively. Following Hedelius et al. (2018), we estimate the difference in XCO and XCO_2 due to their elevation difference. We used the a priori atmospheric profiles (for all days in 2015) from the GGG software, which is used for TCCON retrieval. Based on the same atmospheric profiles, we calculate the XCO and XCO_2 for Caltech and Edwards, respectively. Because of their elevation difference, the columns at the two sites are differed by -0.2 to 0.4 ppm for XCO_2, 5-6 ppb for XCH_4, and 1.5-3.5 ppb for XCO for monthly averages. The monthly means of the differences are shown in the following figure:

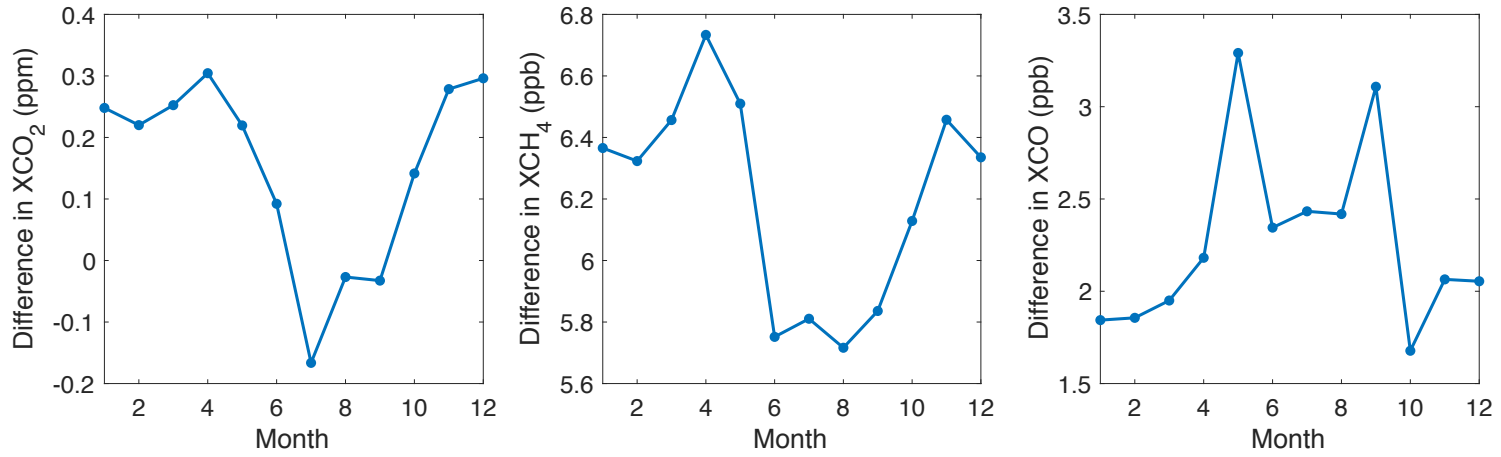


Figure A1. The monthly means of the differences in XCO_2, XCH_4, and XCO due to the elevation difference between Edwards and Caltech sites. The elevations for Caltech and Edwards are 0.23 km and 0.70 km, respectively. These differences are derived following Hedelius et al. (2018).