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Impact of Singapore’s COVID-19 confinement on atmospheric CO₂ fluxes at neighborhood scale

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ABSTRACT

Singapore entered a two-month partial lockdown in Apr. 2020 to curb the spread of COVID-19. The imposed measures in addition to contain the virus spread, cut the emissions of greenhouse gases as many economic activities stopped across the city. The advice of stay-at-home changed the pattern of carbon dioxide (CO₂) emissions within the community. To examine how CO₂ emissions responded to the COVID-19 measures at neighborhood scale, anonymized mobility data released by Google and Apple, and traffic congestion information from TomTom were used to track daily and diurnal changes in emissions related to driving, cooking and metabolic breathing in a residential neighborhood of Singapore, in which the anthropogenic and biogenic fluxes of CO₂ have been widely characterized. During the lockdown, traffic emissions dropped 41%, but emissions from cooking and metabolic breathing increased 21% and 20%, respectively. The uptake of CO₂ by vegetation was not able to offset these emissions, and after adding the biogenic contribution from soil and plants, a net reduction of 24% was found. During the following six months the city got its pace back, with the rate of CO₂ emissions reaching similar or slightly higher levels than those predicted before the pandemic crisis. Unfortunately, the stark drop in emissions was just a temporary relief, which reduced only 3.5% the annual CO₂ flux over the studied neighborhood.

1. Introduction

The COVID-19 (scientifically referred as severe acute respiratory syndrome – coronavirus 2 or SARS-CoV-2) pandemic is teaching us about what we need to do to curb emissions of greenhouse gases (GHG) at different scales. The measures to limit the spread of COVID-19 implemented in different countries have given us an opportunity to evaluate the effectiveness of limiting economic activities to reduce emissions of carbon dioxide (CO₂) to the atmosphere.

Global assessments based on energy demand suggest that CO₂ emissions for individual countries fell 20–30% on average during the peak of the pandemic crisis as people and businesses reduced activity (Forster et al., 2020; Le Quéré et al., 2020; Liu et al., 2020). But they warned that the fall in emissions would be temporary, and would not change the GHG emission budget. However, those studies pointed out that large-scale economic recovery plans could offer an opportunity to enact climate-friendly policies, such as invest in low-carbon technologies that could significantly contribute to mitigate climate change.

In the case of the city-state of Singapore, stringent but not draconian measures came into effect on Apr. 7, 2020 to break the chain of transmission of the virus. These measures included the closure of non-essential businesses and schools, while social gatherings were banned and dwellers were asked to stay at home as much as possible. The majority of Singaporeans understood the rationale behind...
these measures, named ‘Circuit Breaker’, and did their part to comply. This understanding, in addition to contain the spread within the community, cut the CO₂ emissions associated with some of people’s daily activities.

Recommendations to stay at home began in the third week of Mar., but it was until the start of the Circuit Breaker that most people followed the government’s recommendations. The Circuit Breaker lasted 56 days and ended on Jun. 1, 2020. The recovery period was divided in three phases, phases 1 and 2 ran through Jun. 18 and Dec. 28, 2020, respectively, while phase 3 was still in effect at the time of writing (Mar. 2021). Gradually, economic activities resumed and social distancing measures were eased during the three recovery phases. Plans to move out of phase 3 were expected to last until such time there were evidence on vaccine effectiveness in preventing future outbreaks, a substantial proportion of the population were vaccinated, and the rest of the world also had the virus under control.

In this study, the magnitude of the fall in CO₂ emissions experienced in a residential neighborhood of Singapore during the city’s partial lockdown and subsequent recovery period is evaluated using anonymized mobility data released by Google and Apple (Google LLC, 2020; Apple Inc., 2020), and traffic congestion information from TomTom traffic service (TomTom Int. BV, 2020). These data are combined with modeling approaches previously validated and adjusted against direct CO₂ flux observations in such neighborhood to track changes in driving, cooking and breathing emissions. The emissions from these sources are added to CO₂ fluxes related with urban greenery, including contributions from plants and soil, to elucidate the net effect of keeping people at home.

The recent access to mobility and traffic data generated by private enterprises opens an opportunity to update at near-real-time emission inventories of GHG and airborne pollutants that needs to be tested. If accurate emission estimates are obtained at neighborhood scale, I argue that such data in combination with available emission processing tools could be used to evaluate emission variations at city scale.

A detailed analysis of the daily and diurnal CO₂ fluxes will help to determine if the COVID-19 – related decline in emissions was sufficiently deep to produce a significant reduction in the emissions burden at neighborhood scale considering the entire urban ecosystem (i.e., people, people’s activities, and biogenic components). The sudden changes in predicted emissions provide a unique opportunity to assess the effectiveness of enforced or voluntary restrictions to curb the emission of GHG at such scale. Stringent confinements may not necessarily draw a major drop in emissions at community scale, once the whole set of interactions between the elements that make the urban ecosystem is considered.

2. Methods

The anthropogenic and biogenic CO₂ fluxes over the low-rise residential neighborhood of Telok Kurau have been widely characterized (Velasco et al., 2021; Velasco et al., 2013), and the bottom-up approaches developed for their assessment are used in this study to evaluate the impact of the COVID-19 confinement on the net atmospheric exchange of CO₂ at neighborhood scale. Telok Kurau is located in the east side of Singapore (1°18′51.46″ N, 103°54′40.31″ E; 5 m above sea level), consists of 2 to 3 story residential buildings dissected by a dense street network. The neighborhood is densely populated (7500 inhabitants per km²) and is home to 3550 trees and 1990 palms per square kilometer. Thirty nine percent of the area is covered by buildings; roads and other impervious surfaces account for 12% and 34%, respectively, while vegetation covers the remaining 15%. Further details on the neighborhood’s characteristics, and a full description of the methods used to measure and estimate the net CO₂ flux and emissions from individual sources are provided in the references cited in this paragraph.

Briefly, the net CO₂ flux \( (F_C) \) between the urban surface and atmosphere is expressed as:

\[
F_C = E_T + E_H + R_H + R_S + (R_V - P_V)
\]

(1)

where \( E_T \) represents CO₂ emissions from vehicular traffic and \( E_H \) from cooking in households, \( R_H \) is the contribution from human breathing, \( R_S \) from soil respiration (autotrophic and heterotrophic), \( R_V \) from aboveground biomass respiration at night, and \( P_V \) is the CO₂ assimilated by photosynthesis minus the aboveground biomass respiration during daytime. In our case, the net CO₂ flux was obtained from direct eddy covariance measurements of the total CO₂ exchange, including all major and minor anthropogenic and natural emission sources and sinks, during seven years in the neighborhood (Roth et al., 2017). The first three components of \( F_C \) were estimated through bottom-up approaches based on emission factors taken from the literature and activity data collected from local databases or measured in-situ (Velasco et al., 2013). Soil respiration was obtained from the empirical Q₁₀ model adjusted for the soil characteristics and atmospheric conditions of Singapore (Velasco et al., 2021). This model assumes that \( R_S \) responds only to temperature changes in the absence of soil moisture limitations. Finally, the difference between \( F_C \) measured by eddy covariance and estimated emissions, including \( R_S \), represents the aboveground vegetation flux. During daylight hours this difference corresponds to \( P_V \) and during night-time to \( R_V \) (i.e., \( P_V = 0 \) during the night and \( R_V = 0 \) during the day). By convention, positive fluxes indicate emissions and negative fluxes sequestration.

2.1. Emissions during the COVID-19 confinement period

Changes in \( E_T, E_H \) and \( R_S \) during one year after the pandemic onset in Singapore were estimated using people’s mobility data. Changes in emissions from cooking and metabolic breathing were calculated using Google’s charts on mobility trends for places of residence (Google LLC, 2020). Changes in traffic emissions were calculated using Apple’s driving mobility trends and urban congestion data from TomTom (Apple Inc., 2020; TomTom Int. BV, 2020). All emission changes are relative to typical emission levels prior to the pandemic, and quantify only the sheltering in place effect. The changes for each emission source were calculated differently depending on the available data, nature of the confinement, and based on the author’s local knowledge on the ground. The data treatment and
processing details are provided below.

The Google residential mobility trend provides the percentage change of the time that people spent at home by aggregating location data gathered from smartphones on a daily basis. The number of people staying in residence only varies during daytime since everyone comes home at the end of the day, thus the change in population density was not accounted at night and early morning (22–8 h). Note that Singaporeans are in general not early bird people, and economic activities tend to start slightly later compared to other places. Google used the 5-week period from from Jan. 3 to Feb. 6, 2020 as baseline to obtain median values for each day of the week. For the case of Singapore, this period was affected by the Chinese New Year festivities, and yielded a consistent 6–7% overprediction of people staying at home. The trend was then adjusted to data reported for the last two weeks of Feb. and first week of Mar. before the local onset of the pandemic crisis. The first COVID-19 case was reported on Jan. 23, 2020, but no major contention measure was taken until the second week of Mar. when the number of cases started to climb.

The adjusted percentage change in residential mobility was applied to the hourly emissions predicted for cooking and breathing in weekdays prior to the pandemic using bottom-up approaches (see Velasco et al., 2013). A factor of 1.15 and 1.25 was added on Saturdays and Sundays to account for people that usually stay at home on weekends based on observations on the site, and mobility variations reported by Apple and Google.

The driving mobility reports provided by Apple in synchrony with the hourly congestion index computed by TomTom were used to estimate changes in traffic volume. Apple reports relative counts of how many times people request driving directions in one day compared to counts on Jan. 13, 2020; whereas TomTom calculates the extra travel time that drivers experience in comparison to uncongested conditions using real-time traffic information from navigation devices and smartphones. Similar to Google’s mobility reports, Apple’s records turned out to underpredict 15–20% the changes in traffic volume in previous weeks to the pandemic’s onset. TomTom reported a 43% more heavy traffic than on mean days for Apple’s reference day, while Feb. and the first week of Mar. showed congestion levels ~ 10% below than the expected ones, thus Apple’s records on those days were instead used to adjust changes in traffic volume in following days according to the day of the week.

The adjusted daily changes in traffic obtained from Apple’s driving mobility reports at city scale were applied to the traffic volume previously determined for the studied neighborhood prior to the pandemic period, and then the daily CO2 emissions from passenger cars, motorcycles, lorries and trucks were computed using emission factors obtained from the United States Environmental Protection Agency (EPA) MOtor Vehicle Emission Simulator (MOVES) version 2010 (United States – Environmental Protection Agency, 2010), as described in Velasco et al. (2013). For the case of transit buses, emissions were computed in a similar way, but considering a frequency reduction of 30% during the rush morning and evening hours (6–10 h, 17–21 h), and 50% during the rest of the day according to adjustments in the operation service during the Circuit Breaker confinement period (Land Transport Authority, 2020).

During daytime (7–19 h) the average change in TomTom congestion levels relative to those reported for the previous year were similar to the adjusted changes in driving mobility reported by Apple. Thus, to calculate traffic emissions during daylight hours, the hourly traffic volumes determined prior to the pandemic were corrected applying the adjusted Apple’s daily driving mobility trend and adding up the difference between the relative TomTom hourly congestion level with respect to the previous year for that day of the week and the TomTom average congestion level along those 12 hours. The traffic volumes from midnight to 5 h were similarly corrected using Apple’s driving mobility records and TomTom’s congestion levels for those hours. Traffic volumes at 6 h and 20–23 h were linearly interpolated.

Contributions from soil respiration were modeled using hourly records of ambient temperature from the closest weather station (Tai Seng station, Meteorological Service Singapore) considering that 15% of the neighborhood’s surface is covered by vegetation (i.e., trees and turfggrass). The ambient temperature was converted to soil temperature at 2 cm deep using an empirical correlation previously determined (Velasco et al., 2013), which in turn was applied to a locally adjusted Q10 model to calculate the CO2 efflux from soil (Velasco et al., 2021). The CO2 flux from aboveground vegetation obtained from the difference between the net CO2 flux measured by eddy covariance in previous years and the estimated anthropogenic emissions and soil respiration, was assumed that it would not change during the pandemic period (Velasco et al., 2013).

3. Results

Google and Apple mobility reports indicate that the daytime hours spent at home by Singaporeans during the two-months partial lockdown (i.e., Circuit Breaker) increased 73%, 51% and 43% on weekdays, Saturdays and Sundays, respectively, while traffic decreased 51% both on weekdays and Saturdays, and 48% on Sundays. Along the three recovery periods, the trend of people staying at home during daytime decreased gradually. Phase 1 saw an excess of people staying at home of 69%, 44% and 39% on weekdays, Saturdays and Sundays, respectively. At the time of phase 2 the excess of people dropped to 25%, 12% and 11%, and 13%, 4% and 4% at the time of phase 3, respectively.

Regarding to vehicular traffic, it decreased to 32% by the end of phase 1, but returned to mean pre-pandemic levels by the third week of Jul. after five weeks of starting phase 2, continuing to increase for another month, until exceeding mean levels by 7% in Aug. This increase was temporal, traffic had once again decreased to 5% below mean levels by Nov. In Dec., the holiday festivities drew a further increase in traffic, but it returned to mean levels once phase 3 started. A similar trend in traffic congestion was reported by TomTom. During the confinement period, congestion fell to minimum levels, with trips taking as maximum 5% more time in rush hours than during uncongested conditions.

During phase 1 many economic activities resumed, but social and entertainment activities remained closed, as well as retail and eatery outlets. People were advice to leave only for essential activities and keep working from home if possible. During this period, schools gradually re-opened following strict safe distancing measures. After twelve days, once the infection rate in the community had
declined and become stable, Singapore moved into phase 2, and many other activities resumed, except those where people come into close contact for long periods of time, such as entertainment venues. However, telecommuting and safe distancing were still recommended, as well as wearing masks outside home. Phase 3 began once the local transmission cases dropped to almost zero every day. This eased capacity limits in public places and allowed other economic activities to resume (Ministry of Health Singapore, 2021).

The effect of the partial lockdown was to cut on average 38% (4.73 Mg km\(^{-2}\) day\(^{-1}\)) CO\(_2\) emissions from traffic, and raise 23% (0.29 Mg km\(^{-2}\) day\(^{-1}\)) and 29% (0.95 Mg km\(^{-2}\) day\(^{-1}\)) emissions from cooking and breathing at neighborhood scale on weekdays during the two-months Circuit Breaker phase relative to mean level emissions prior to the pandemic period. Adding the biogenic contribution, including soil and plants, the net CO\(_2\) flux dropped 21% (3.48 Mg km\(^{-2}\) day\(^{-1}\)) in total on weekdays. Major reductions in traffic flow on weekends produced deeper drops in the net CO\(_2\) flux, 34% (6.28 Mg km\(^{-2}\) day\(^{-1}\)) and 29% (4.19 Mg km\(^{-2}\) day\(^{-1}\)) on Saturdays and Sundays, respectively. Fig. 1 shows the diurnal distribution of emission contributions on weekdays during the Circuit Breaker phase, including the predicted net CO\(_2\) flux prior to the pandemic period for comparison purposes.

Fig. 2 shows the day-to-day changes in the net CO\(_2\) flux and contributions from each emission source and sink for one-year period starting on Feb. 15, 2020, as well as the relative variations compared to the period Feb. 15 – Mar. 20, 2020, in which no changes had yet been registered in people’s mobility. Changes in the emissions variability according to the day of the week are evident on Saturdays and Sundays. On regular days (i.e., no affected by the COVID-19 pandemic), the net flux is usually 2% higher on Saturdays than on weekdays due to increases in breathing (30%) and cooking emissions (11%) from more people staying at home, despite of a decrease in traffic emissions (6%). But on Sundays, the drop in traffic emissions (32%) exceeds increases in breathing (35%) and cooking (16%) emissions, and leads a 15% reduction in the net CO\(_2\) flux. During the pandemic period the relative drop on weekends with respect to weekdays increased, no higher fluxes on Saturdays than on weekdays were observed as on regular days during the Circuit Breaker phase. Saturdays and Sundays saw net CO\(_2\) fluxes 10% and 22% lower than on weekdays, respectively.

The total change in emissions during the 56 days of the Circuit Breaker phase was estimated to amount – 275, 15 and 38 Mg km\(^{-2}\) from driving, cooking and breathing, which summed – 222 Mg km\(^{-2}\) after adding the biogenic flux contribution. This represented a 24% drop in the net CO\(_2\) flux over the neighborhood considering weekdays and weekends. As a percentage, traffic emissions dropped 41%, but emissions from cooking and breathing increased 21% and 20%, respectively. During the 18 days prior to the partial lockdown (Mar. 20 - Apr. 6, 2020), the initial recommendations to limit the virus spread cut 11% the net CO\(_2\) flux. The 17 days of phase 1 recovery period saw a 14% reduction, but the first 7–8 weeks of phase 2 experienced a gradual rebound, restoring and even exceeding predicted CO\(_2\) flux levels on regular days as a consequence of an increase in traffic, as already described. A net CO\(_2\) flux increase of 7% was attained in Aug. Fortunately, vehicular traffic returned to regular levels one month later, and continued to decline in the next three months, drawing a 3% fall below mean levels in exhaust emissions, and a net CO\(_2\) flux reduction of 1% by Nov. The holiday festivities and announcement of the end of phase 2 in Dec. drew an increase of 7% in traffic emissions and swelled 6% the net CO\(_2\) flux with respect to mean pre-pandemic levels. Once phase 3 had started, emissions from traffic, cooking and breathing on days no affected by public holidays were on average 1%, 3% and 2% higher than expected, respectively, and after adding the biogenic flux they yielded a net CO\(_2\) flux 1.5% higher regarding to pre-pandemic conditions. Christmas, New Year and the week affected by the Chinese New Year Spring Festival triggered spikes in the emission trend as can be seen in Fig. 2.

![Diurnal cycle of the net CO\(_2\) flux and individual contributions from different emission sources and sinks in the residential neighborhood of Telok Kurau, Singapore during the COVID-19 confinement period, locally named ‘Circuit Breaker’. Data are weekday averages. The predicted flux prior to the pandemic period is included for comparison purposes. The daily CO\(_2\) contributions by emission source or sink are included at the right. Figures in black and red fonts are predicted fluxes prior and during the confinement period, respectively. The percentage figures next to the arrows indicate the relative change in emissions. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)](image_url)
4. Discussion

4.1. Implications for climate change mitigation policies

The total reduction of 217 Mg km\(^{-2}\) yr\(^{-1}\) in the net CO\(_2\) flux considering the entire urban ecosystem (i.e., including contributions from vehicular traffic, cooking, metabolic breathing, plants and soil) throughout the year affected by the COVID-19 pandemic (Feb. 15, 2020 – Feb. 14, 2021) was equivalent to 3.5% of the annual flux predicted prior to the virus emergence within the boundaries of the residential neighborhood of Telok Kurau. It is not a negligible amount, but it had a tremendous economic cost. Singapore’s gross domestic product (GDP) temporally shrunk on a year-on-year basis 13.3%, 5.8% and 2.4% in the second, third and fourth quarters, respectively, resulting in annual economic shrink of 5.4% (Ministry of Trade and Industry Singapore, 2021).

Indeed, severe disruptions in daily activities can cut direct emissions of CO\(_2\) within the boundaries of the community. However, measures to mitigate climate change should rather focus on reducing the 22 Mg yr\(^{-1}\) of CO\(_2\) associated to the production of all goods consumed by an average Singaporean; this per capita emission figure was obtained from disaggregated emissions data at national scale released as part of the Global Carbon Budget 2018 (Global Carbon Project, 2018).

In perspective, the amount of CO\(_2\) that was not released to the atmosphere during the pandemic period in the studied neighborhood, is equivalent to the annual carbon footprint of 10 dwellers of the 7500 living there per square kilometer. Therefore, policies to cut emissions of GHG should target emissions that originate outside residential areas, and change people’s attitudes that indirectly worsen emissions at city scale. For example, government’s recommendations to set air conditioning at temperatures of 25 °C and above in residences and public buildings might become official rules, and contribute to reduce energy consumption and associated CO\(_2\) emissions (Ministry of the Environment and Water Resources, 2016).

Fig. 2. Daily fluxes of CO\(_2\) (a) and relative changes in emissions by emission source (b) prior the pandemic period (Feb. 15 – Apr. 6, 2020), during Singapore’s partial lockdown locally named Circuit Breaker (Apr. 7 – Jun. 1), and subsequent recovery periods: phase 1 (Jun. 2–18, 2020), phase 2 (Jun. 19 - Dec. 28, 2020), and phase 3 (Dec. 29, 2020 - still ongoing at the time of writing), in the residential neighborhood of Telok Kurau. The dashed line in the upper panel indicates predicted fluxes prior to the pandemic period.
Policies to make of Singapore a ‘car-lite’ city will contribute to cut emissions at neighborhood scale. In fact, apart from reductions in traffic emissions, it is unrealistic to achieve significant reductions in other emission sources without reducing the number of inhabitants at such scale. Therefore, current actions and plans to reduce the city’s reliance on cars and move towards public transport, cycling and walking will help to build sustainable neighborhoods lowering the emission of GHG (Land Transport Authority, 2018).

With respect to urban vegetation, the real capacity of plants to offset anthropogenic emissions is limited or null (Velasco et al., 2016), in addition that in many neighborhoods there may not be enough space to significantly increase green coverage. However, the current greening strategy aiming to restore nature into the urban fabric to mitigate the harshness of the built environment may reduce indirectly CO₂ emissions by providing shade to buildings, and thus reducing the use of air conditioning (National Parks Board, 2019). More naturalistic landscapes like those already in construction along selected road sides trying to replicate the natural structure of forests as far as possible will require much less maintenance, and therefore will reduce the GHG emitted by gasoline-powered gardening equipment, and minimize waste (i.e., clippings and trees debris), which depending on its disposal may end adding up more carbon to the atmosphere. During the 4 months more severely affected by the pandemic, grass-cutting and weeding activities ground to a halt, and it meant that 7.8 Mg km⁻² of CO₂ were not emitted by mowing the neighborhood’s turfgrass using a push mower every third week following the approach developed by Velasco et al. (2021) to estimate emissions related to turfgrass maintenance.

4.2. Limitations of emission estimates based on changes in people’s mobility and traffic congestion

The CO₂ flux and emission estimates presented here should be seen as a smart approximation based on changes in people’s mobility obtained from anonymized smartphones data used to feed map services of Google, Apple and TomTom, rather than on absolute activity data. The assumptions made were based on the data available during the pandemic period, and seven years of CO₂ flux observations using a tall eddy covariance flux tower in the center of the neighborhood (Roth et al., 2017). This tower was unfortunately dismantled in 2017 and it was not feasible to collect direct CO₂ flux data during the pandemic crisis to adjust the modeling approach based on people’s mobility to estimate anthropogenic emissions. The time history of these type of mobility data is too short and it is not possible to use past flux observations to validate such approach.

The consortium of urban flux towers in Europe connected through the Ecosystem Thematic Centre of the Integrated Carbon Observation System (ICOS) kept running a number of towers in different cities during this period. These CO₂ flux measurements at local scale will help to test and adjust modeling approaches like those proposed here based on urban mobility data compiled originally for other purposes. An initial analysis of such CO₂ fluxes clearly showed the initial effects of the lockdown at each city, and the corresponding changes in emissions according to individual restrictions and characteristics of monitored neighborhoods (Papale et al., 2020). A detailed analysis for the case of Innsbruck, Austria showed a reduction of 38% in the net CO₂ flux measured at a site near the city center during the lockdown period, of which 59% was attributed to less vehicular traffic (Lamprecht et al., 2021).

An analysis of the uncertainties in the emission estimates presented here is not feasible because of the nature of the mobility reports and congestion levels based on changes in phone locations, and a lack of information on the methodology and statistics used by the ‘tech giants’ acting as data providers. Only Google has a public document in which the aggregation and anonymization process applied to generate the community mobility reports is described (Aktay et al., 2020). It adduces at most a 5% risk of being wrong by more than 10% the daily records on mobility change. Regarding to representativeness, being Singapore a city-state leading the use of smartphones with a penetration over 90%, and most of users being part of social networks and using their phones frequently to request directions (Google, 2020), the mobility data is expected to be representative of the entire population across the city.

The unprecedented recent access to mobility and traffic data generated by private enterprises gives an opportunity to adjust timely and easily emission estimates based on bottom-up approaches. Emission inventories based on such approaches rely on the collection of annual or monthly data related to energy consumption, traffic volume and industrial activity, that are always released a few months later. Urban flux towers have demonstrated to be valuable tools to test the accuracy of emission estimates at temporal and spatial resolutions required for gridded emission inventories, thus helping to improve estimates at city scale (e.g., Järvi et al., 2019; Björkgren and Grimmond, 2018; Velasco et al., 2009). The combination of both, changes in people’s mobility and traffic congestion, and flux tower measurements can provide the data needed to update at near-real-time emission inventories of GHG and airborne pollutants through the application of advanced emission processing tools integrated often into forecasting air quality models (e.g., Guevara et al., 2020). For this endeavor, Google, Apple, TomTom and any other big-data provider are encouraged to continue releasing mobility data, as well as to make their postprocessing methods less intriguing, providing technical details that make possible to assess uncertainties.

5. Conclusions

The local response to the COVID-19 pandemic showed that a drastic reduction of economic activities is not sufficient to act against climate change in an effective way. The advice to stay-at-home reduced traffic, but increased the consumption of natural gas for cooking, as well as the contribution from metabolic breathing within the boundaries of the community during daytime. The drop in traffic was sufficient to offset the emission increase related to breathing and cooking, and led a net reduction during the confinement period at neighborhood scale. However, contributions from cooking and breathing did not change at city scale, only accounting then the reductions triggered by less traffic and the halt of many economic activities outside residential areas.
Transformative changes in people’s attitudes inside and outside the home are needed to effectively mitigate climate change. Holistic policies that consider the role of people, people’s activities and the biogenic component (soil and plants) in carbon dynamics will make possible to build sustainable cities and regions that minimize the emission of GHG, without the need of extreme measures that affect the economy and dwellers’ wellbeing.

Declaration of Competing Interest

The author declare that he has no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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