Clear evidence of reduction in urban CO_2 emissions as a result of COVID-19 lockdown across Europe

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The COVID-19 lockdown has affected our lifestyles and work, forcing us to stay at home. This has strongly reduced road traffic and economic activities particularly in cities, and, consequently, cut down emissions of carbon dioxide (CO_2) to the atmosphere. Whilst lockdown does not affect baseline emissions such as ecosystem respiration and CO_2 exhaled by humans and animals, home confinement may impact the spatial distribution and temporal dynamics of, e.g. emissions from domestic and commercial heating.

Although this signal is not strong enough to markedly change global atmospheric concentrations of CO_2 (e.g. see ICOS news https://www.icos-cp.eu/event/917) because of e.g. long-range transport and mixing of gases in the atmosphere, changes in emissions are clearly observable at local-scale. They can also be directly measured at near real-time with micrometeorological tools such as the eddy covariance (EC) technique. EC is used globally to study ecosystem-atmosphere exchange of CO_2, and the number of urban flux measurement towers has been growing steadily over the past couple of decades.

The core principle of EC measurements is that the net exchange of a specific gas, i.e. the sum of all sources (emissions to the atmosphere) and sinks (removal from the atmosphere), can be determined from simultaneous, co-located, high-frequency measurements of vertical wind speed and gas concentration. This method is used in ICOS to monitor exchange of CO_2, methane (CH_4) and nitrous oxide (N_2O) mainly between vegetated ecosystems (forests, crops, grasslands, mires) and the atmosphere, and it is globally used at more than 1000 sites.

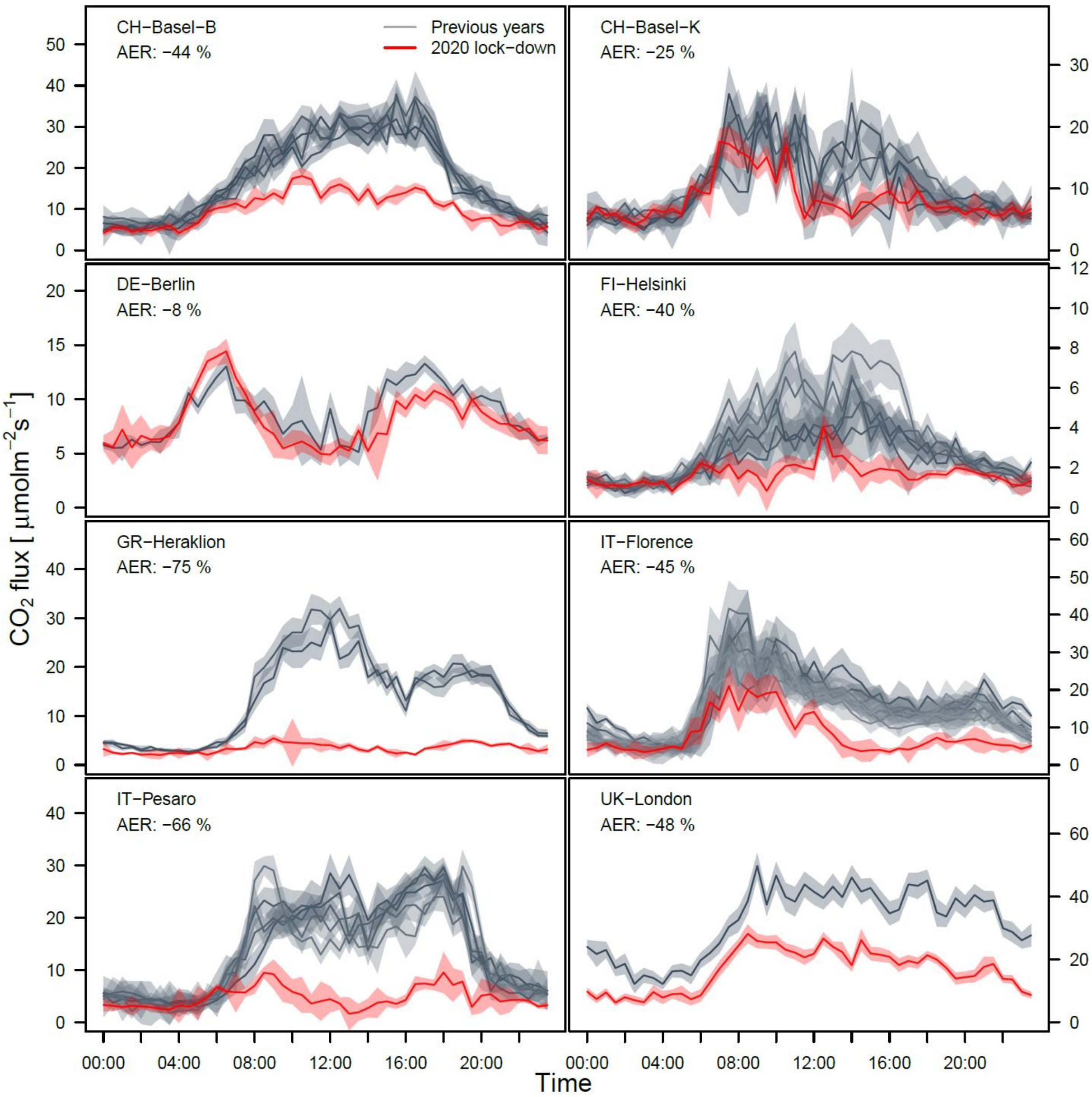
In cities and urban neighbourhoods, the net emissions measured using EC are comprised of the cumulative contributions from multiple anthropogenic sources, such as fossil fuel combustion by vehicular traffic, heating and cooking as well as biogenic emissions (plant, animal and human respiration, sewage) and sinks (e.g. uptake of CO_2 by urban green spaces).

The measurements, expressed in $\mu mol\ CO_2\ m^{-2}\ s^{-1}$, have a positive sign when the flux is from the surface to the atmosphere (i.e. an emission, as is typical in urban areas) and negative when CO_2 is drawn down e.g. through the process of photosynthesis.

The ICOS network includes one urban Associated station in Helsinki on a peri-urban area (Kumpula) managed by the University of Helsinki, but connections with other research groups all around Europe allowed the ICOS Ecosystem Thematic Centre (ETC) to open up a dialogue and coordinate a study of emissions measured at eight urban EC stations: Pesaro and Florence (both in Italy and managed by Italian National Research Council CNR), Heraklion (Greece; managed by Foundation for Research and Technology Hellas FORTH), London (UK; managed by the UK Centre for Ecology and Hydrology and the University of Reading), Berlin (Germany; managed by Technische Universität Berlin) and two sites in Basel (Switzerland; managed by University of Basel).

Lockdown affected emissions of CO_2 at all participating urban EC sites, but the magnitude of individual reductions in emissions varied due to the characteristics of the sampled districts and the stringency of the lockdown restrictions. Indeed, lockdown policies in response to the COVID-19 emergency varied and continue to vary between countries, ranging from a full cessation of all activities (like in Italy and Greece where people were allowed to go for a walk within their neighbourhood only in specific cases), to softer approaches based on recommendations of social distancing (e.g. Helsinki where no curfew took place). In addition, the areas covered by the EC observations (termed flux footprint; approximately up to about 500 m around the measurement tower and even several km in the case of the London tall tower) are heterogeneous: some sites are characterized by a dense road system for which traffic is the main emission source (e.g. Pesaro, London), whilst domestic heating makes a strong contribution to the total CO_2 emissions in cities like Florence with significant residential or pedestrian areas. The flux footprints of other EC stations (e.g. Basel, Berlin, London) have relatively large fractions of vegetation and water in specific sectors, whilst commercial emissions and traffic dominate in Heraklion. All this is clearly visible when comparing measurements prior to and after lockdown. The effects of the lockdown on CO_2 emissions are shown in Figure 1, which compares the average diurnal pattern of urban emissions during the 2020 lockdown period with the same spring period during previous year(s).

All the monitored cities experienced a reduction in emissions, ranging from 8% in a highly vegetated urban area of Berlin, Germany, and 75% in the city centre of Heraklion, Greece. The tower in Heraklion observed the largest reduction, since it is in an area characterized by dense commercial activities and intense road traffic that were completely stopped during the lockdown. Pesaro (Italy) has also significantly reduced its daily emissions, up to a third, as a consequence of the strong restrictions in traffic that characterise the emission in the area with the typical two peaks in the morning and in the afternoon rush hours. In Florence and Helsinki the emissions are a combination of reduced traffic and economic activities, while increased domestic heating and human metabolism partly counterbalanced the reduction. London's emission sources show some similarities with those of Florence and Helsinki (large contributions from traffic and the commercial sector), but differs on the residential contributions: in a business-as-usual scenario, the weekday population during daytime of central London can increase 10-fold due to the influx of commuters, but this decreased strongly with lockdown. In Berlin, the moderate reduction in traffic has been counterbalanced by domestic emissions and the presence of vegetation, leading to relatively small fluxes. Basel-B and Basel-K have similar land cover distributions, but at Basel-B the traffic density is 2-fold that of Basel-K, where the prevailing wind sectors have relatively small traffic contributions.



CH−Basel−B
AER: −44 %
Previous years
2020 lock−down
CH−Basel−K
AER: −25 %
DE−Berlin
AER: −8 %
FI−Helsinki
AER: −40 %
GR−Heraklion
AER: −75 %
IT−Florence
AER: −45 %
IT−Pesaro
AER: −66 %
UK−London
AER: −48 %
CO_2 flux [µmolm^{-2}s^{-1}]
Time
00:00
04:00
08:00
12:00
16:00
20:00

Figure 1: CO_2 flux diurnal cycles as measured in eight neighbourhoods by flux tower sites across seven European cities during the COVID-19 lockdown period (red line). For comparison purposes, flux data collected in previous years during the same period are also presented (grey lines). Shaded areas are standard errors of the mean flux and provide insight into the day-to-day variability. The average emission reduction (AER) observed at each site is presented as the percentage difference with respect to previous years.

The high temporal resolution of the flux measurements (half-hourly) allows the beginning of the lockdown, and its effect on CO_2 emissions, to be tracked precisely. Figure 2 shows fluxes over the last three months from February 5th to May 6th, and highlights the lockdown period in the different countries. A general reduction in emissions with respect to previous years can be seen in all cities during their respective lockdown periods (red bars compared to grey bars). In some cases (e.g. Florence, London and Heraklion) emissions began decreasing some time before the official lockdown was implemented, in response to recommendations to reduce travel and work from home as much as possible.

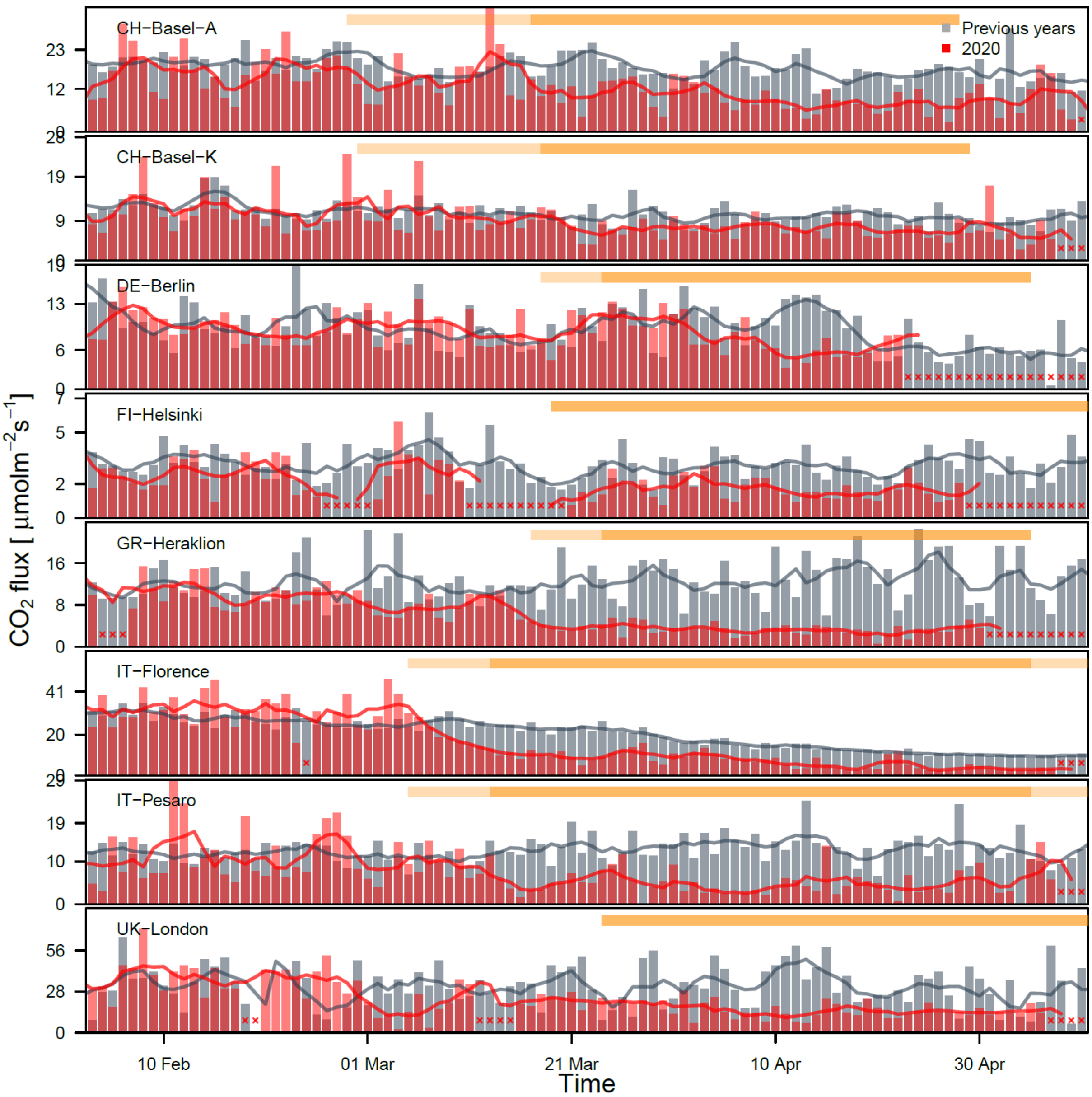


Figure 2: Average daily fluxes from February 5th to May 6th 2020 (red bars) and average of the previous years during the same period (grey bars). Lines represent 3-days moving window averages to better highlight the general trend. The dark-orange horizontal bars

cover the periods of official lockdowns while the light-orange bars indicate periods of partial lockdown or general restrictions (e.g. schools closed, personal contact reductions, mobility constraints). The red crosses indicate days without measurements.

The flux measurements will also be very important for monitoring the emission patterns in the coming weeks and months, when private cars will possibly be preferred to public transports to avoid crowds. This might cause a fast growth of emissions that may even exceed those of the pre-lockdown period. On the other hand, some cities are investigating whether the COVID-19 lock-down period could be used as a trigger to increase walking and cycling as an alternative to car use.

A more comprehensive analysis and a paper including more measurements is currently under preparation, however, this preview and qualitative analysis demonstrates the potential of local-scale eddy-covariance flux measurements in cities: firstly, they can help detect changes in emission dynamics at high temporal resolution. Secondly, they can complement other information on anthropogenic emissions, such as traffic and energy consumption data, high precision measurements of atmospheric concentrations of greenhouse gases, or satellite data. Thirdly, they can help to validate emission scenarios of other atmospheric pollutants.

In an inventory conducted in 2018 in the context of the CHE H2020 European project, 80 urban flux towers were listed globally (only part of them still operational), highlighting an important scientific community working on these "anthropogenic ecosystems". In order to ensure the stability of this unique network and to aid international collaboration, the ICOS Ecosystem Thematic Centre initiated a discussion for a more structured organization of the urban network. Thus, the "1st ICOS Workshop on strategies to monitor greenhouse gases in urban environments" was held in Finland in 2019. In the workshop, the scientists established a roadmap to develop standard procedures for the acquisition and processing of these particular measurements, with the aim to possibly include them in research infrastructures like ICOS, in partnership with programmes such as WMO IG3IS.

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***Figure 2b**, a simplified-version of the figure 2: Average daily emissions from February 5th to May 6th 2020 (red area) and average of the previous years during the same period (grey area). The dark-orange horizontal bars cover the periods of official lockdowns while the light-orange bars indicate periods of partial lockdown or general restrictions (e.g. schools closed, personal contact reductions, mobility constraints).*