METROLOGY FOR CLIMATE ACTION
26–30 SEPTEMBER 2022

Bureau International des Poids et Mesures

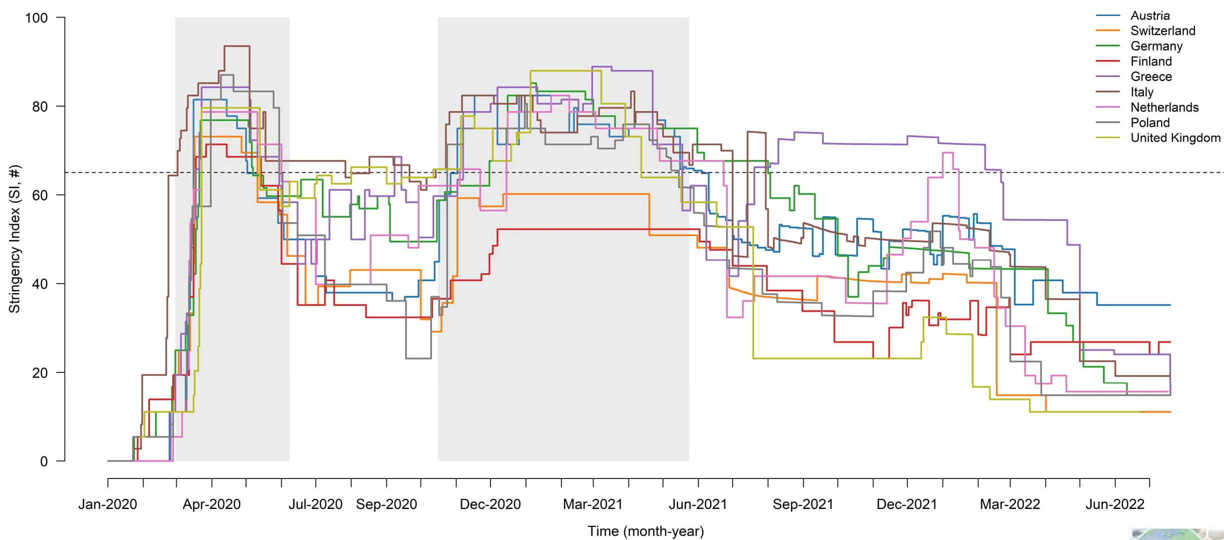
WORLD METEOROLOGICAL ORGANIZATION

Monitoring of urban CO_2 emissions during the COVID-19 lockdowns and of their subsequent evolutions.

Giacomo Nicolini, Gabriele Antoniella, Federico Carotenuto, Andreas Christen, Philippe Ciais, Christian Feigenwinter, Beniamino Gioli, Stavros Stagakis, Erik Velasco, Roland Vogt, Helen C. Ward, Janet Barlow, Nektarios Chrysoulakis, Pierpaolo Duce, Martin Graus, Carole Helfter, Bert Heusinkveld, Leena Järvi, Thomas Karl, Serena Marras, Valéry Masson, Bradley Matthews, Fred Meier, Eiko Nemitz, Simone Sabbatini, Dieter Scherer, Helmut Schume, Costantino Sirca, Gert-Jan Steeneveld, Carolina Vagnoli, Yilong Wang, Alessandro Zaldei, Bo Zheng, Dario Papale

Good morning, I am Giacomo Nicolini, a researcher at the Euro Mediterranean Center on Climate change in Italy, and also a member of the ICOS Ecosystem Thematic Center.
I will show you some results from a study we made on the impact of the COVID-19 pandemic on urban CO2 fluxes.

Covid waves 2020-2022

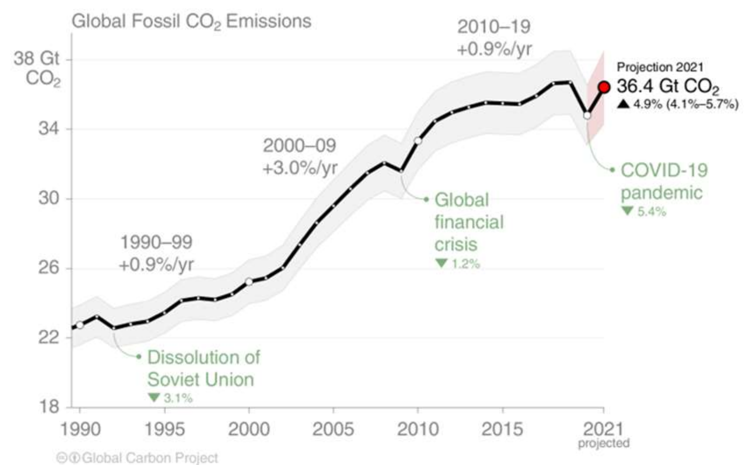


METROLOGY FOR CLIMATE ACTION 26-30 SEPTEMBER 2022

We all experienced the policy measures taken by our countries to tackle the spread of the COVID-19 pandemic. Here we see the evolution, from 2020 to recent days, of the level of such restrictions quantified by a number that varies between 0-100 named “stringency index”, released by the Oxford COVID-19 Response Tracker.

The SI is a composite measure of 9 response metrics, among which there are school and workplace closures, closures of public transport, stay-at-home requirements, restrictions on internal movements ecc.
We used this index to define different periods with different stringency, in primis the lockdowns as highlighted here, for the cities we used in our study.
>>

Global fossil CO_2 emissions



Source: Friedlingstein et al 2021

As recently shown by the Global Carbon Project, there was a drastic reduction of the fossil fuel emission at global scale in 2020, 5.4%, as a consequence of the first wave of the COVID-19 pandemic. The projection for 2021 was for a recovery of the emissions to pre-covid levels.
In our study we tested if this trend was still visible also at local scale.

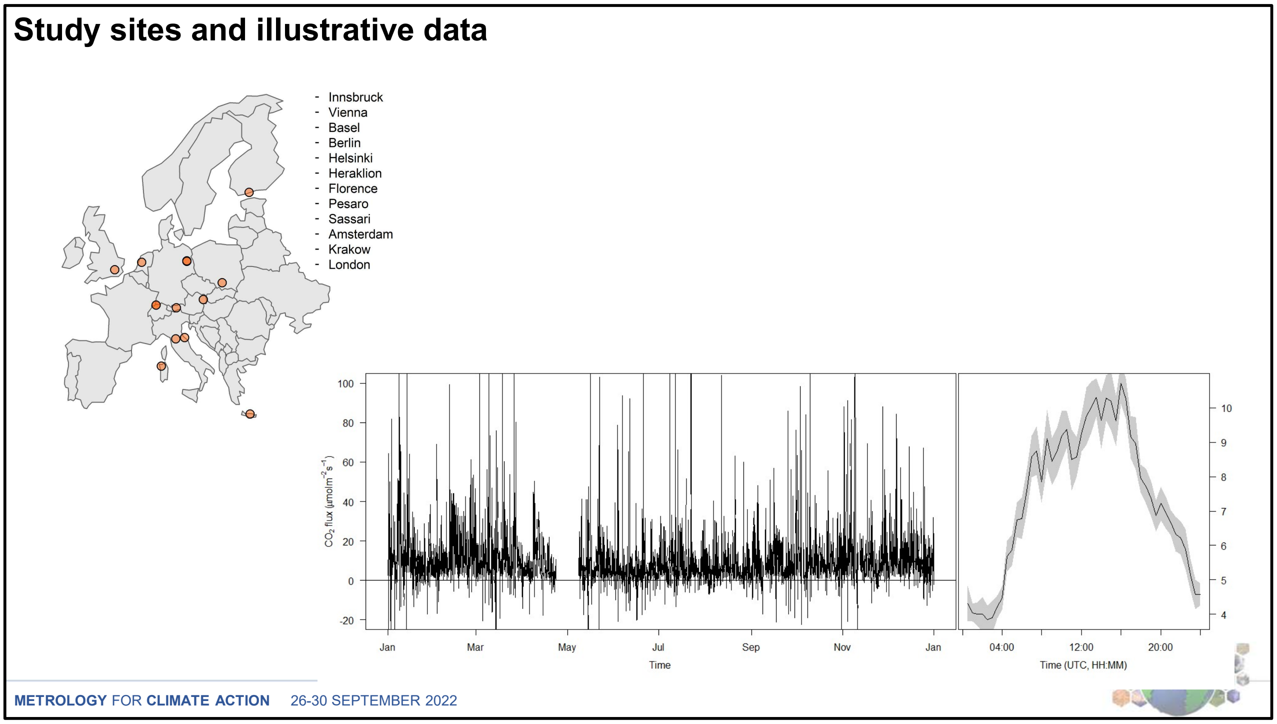
Eddy covariance

- Micrometeorological technique, based on gas-wind covariance
- Output: continuous data, real time, @ 30 minutes
- Footprint: source area extent (10-1000 m, ~ wind direction, …)
- Core ICOS Ecosystem measurement technique


HECKOR tower, Heraklion (Greece) © RSLab

METROLOGY FOR CLIMATE ACTION 26-30 SEPTEMBER 2022

The data on which we based our study are time series of CO2 fluxes as estimated by the eddy covariance technique.
The EC is a micrometeorological technique which allow to compute the gas flux basing on the covariance between its concentration in air and the vertical wind speed.
The resulting flux data are seamless series, potentially collected almost in real-time, generally with a 30 minutes resolution.
The estimates are integrated over a certain area below the measurement points (so called footprint), which extends for like 10s to 1000s meters and the shape of which is determined wind distribution, the atmospheric conditions and the characteristics of the surface.
The EC is the core technique at the base of the data collected within the ICOS Ecosystem network >>



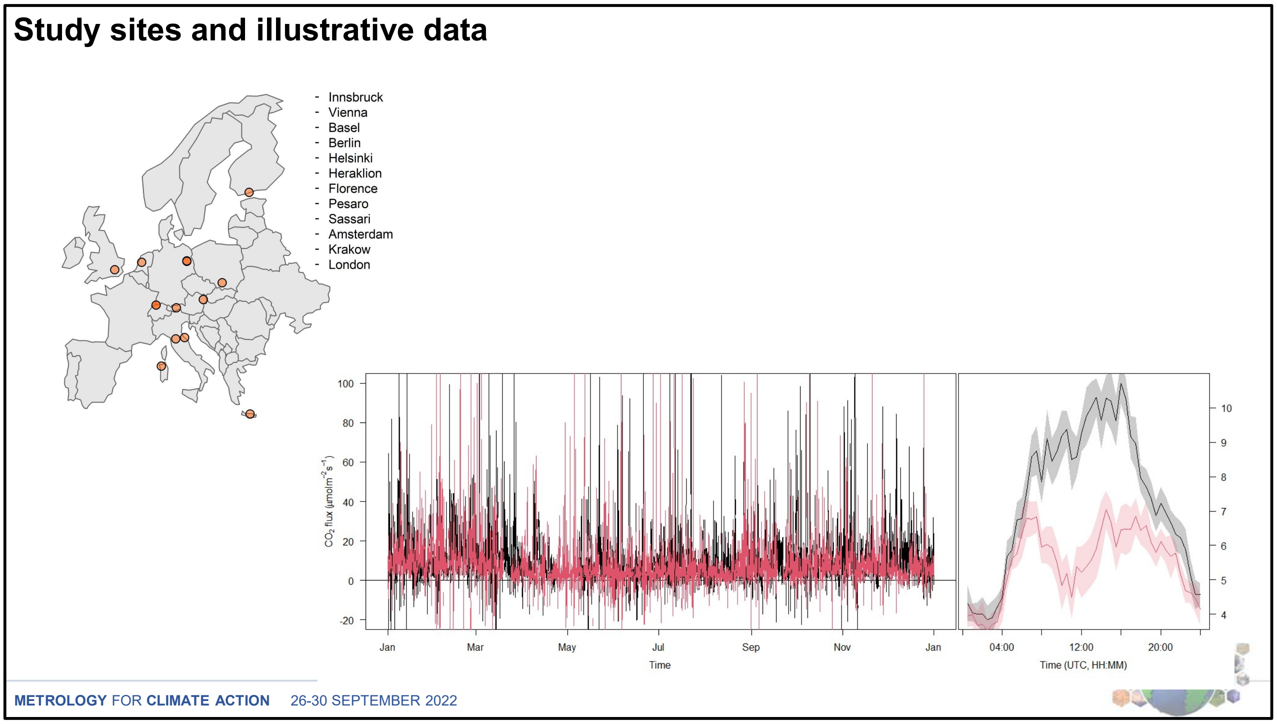
Our dataset, which includes both eddy covariance and meteorological variables, is made by data coming from 12 European cities .

Here below,

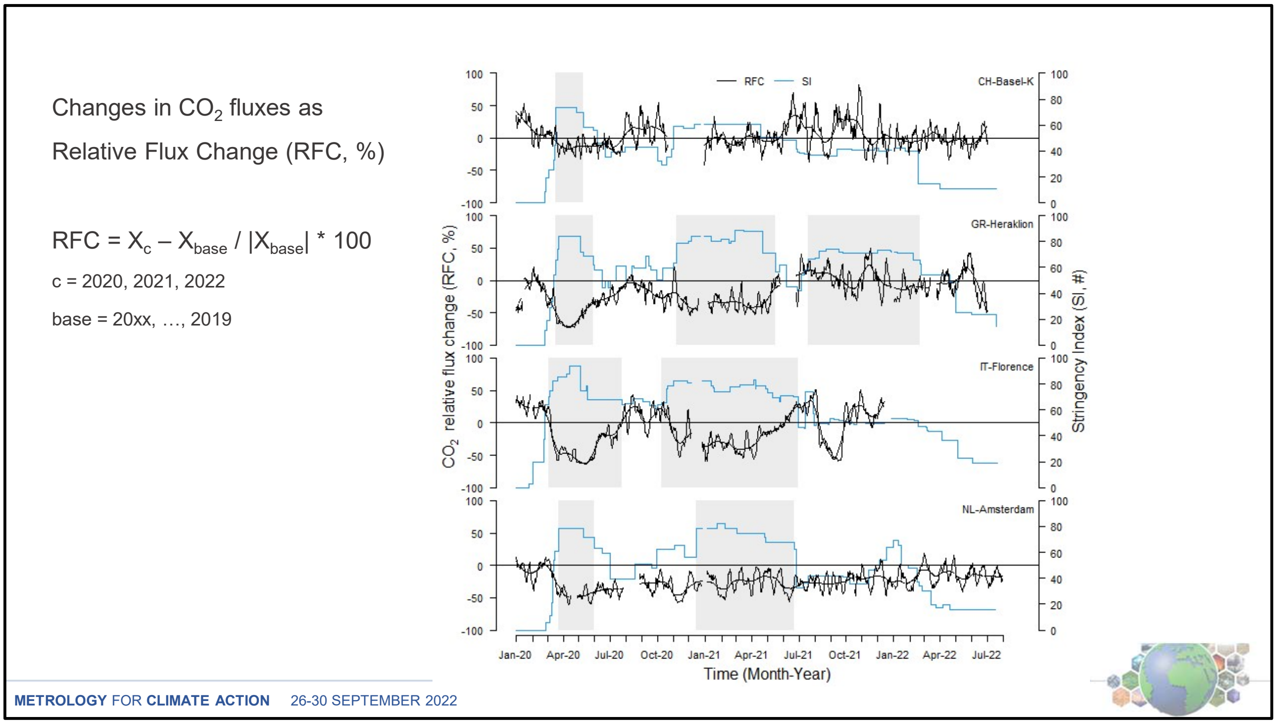
on the left you can see an illustrative yearly timeseries of CO_2 fluxes during business as usual conditions for one of the considered cities.

You can see the typical variability and for example the seasonal variations with generally higher fluxes during the cold season. The convention is to consider positive fluxes as CO_2 emissions and negative fluxes as sinks.

On the right, you can see a typical diel cycle, with the emission peak during daytime, when people's activities generally take place. >>



If we do the same for the year 2020, we suddenly see that something happened: especially by looking at the diel cycle, we see that fluxes are in general pretty lower, and also the trend is different!
In this study we explored these differences, trying to understand their magnitude and causes. >>



So, getting into the thick of the analysis, I show you here some examples of such differences which we estimated starting from the beginning of the 2020. To allow for the comparisons of the data among cities, we used relative numbers instead of the actual CO2 fluxes. We used a quantity named Relative Flux Change which is simply the relative change of the analysed fluxes during the pandemic in comparison of their concurrent values in the previous years.

In this example, showing a selection of 4 cases, we first see that the anti-correlation between the RFC and the level of restriction is evident. This was true far all the cities we considered.

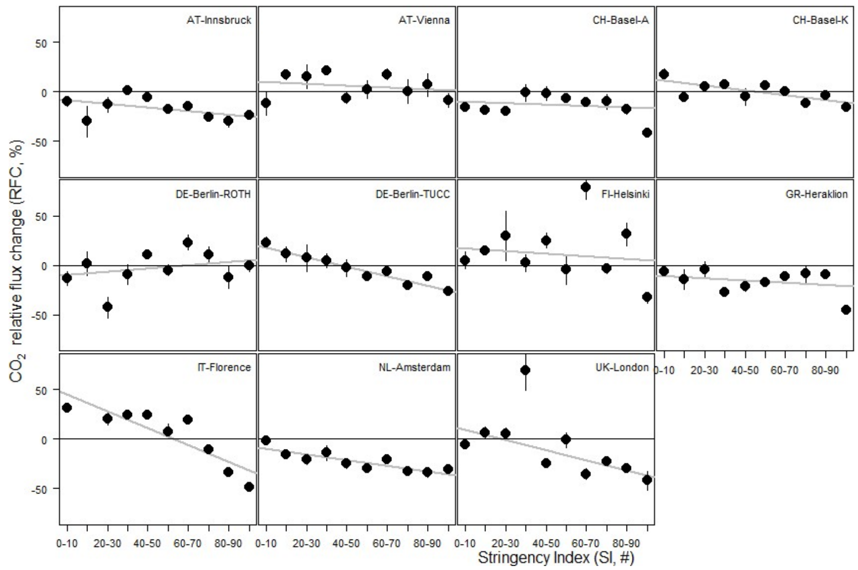
And also that the response of the emission was very fast, starting to decrease as soon as the restrictions became stricter.

You see here that for example at Basel (Switzerland), there have been only one lockdown. In this period emissions decreased, but then the changes start to variate crossing the 0, meaning a return to business as usual emission levels.

On the contrary at Heraklion (Greece) there have been 3 lockdowns. In the 3 of them the emissions were reduced, but progressively in a lesser extent, starting to approach 0 already during the 3rd lockdown

Florence and Amsterdam for example experienced 2 lockdowns and the consequent emission reductions, but in Amsterdam we can see the CO2 emissions remained lower than in the normal conditions almost up to this Summer. >>

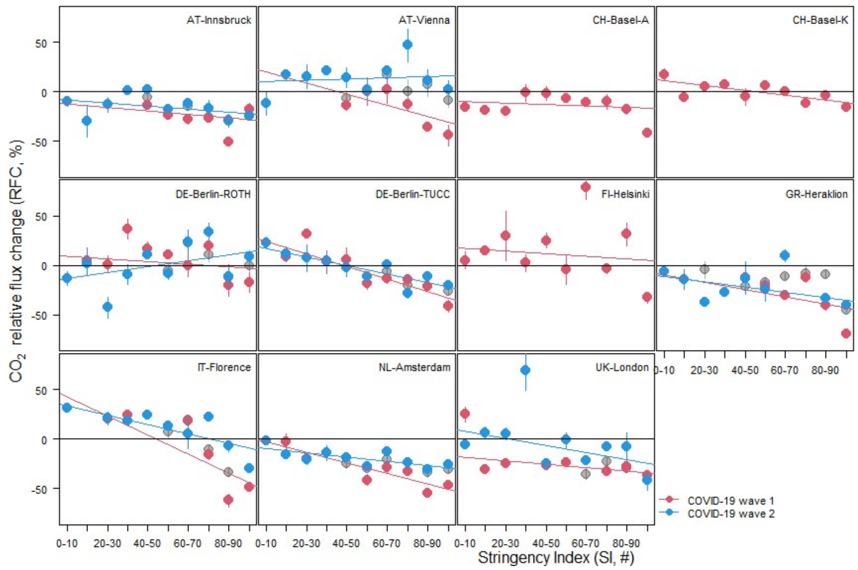
CO_2 flux relative change and restrictions - 1



METROLOGY FOR CLIMATE ACTION 26-30 SEPTEMBER 2022

So if we look at the single cities, putting into relation the intensity of emission reductions (y axis) with the intensity of social restrictions, we see that in the very most of the cities the relation is clear: starting from Si values of 50-60, the emissions start to decrease reaching the minimum at the higher level of stringency.
But as we noted before, the restrictions during the first and the second COVID waves, although with similar stringency level, didn't impact on the urban CO2 fluxes in the same way.
So if we separate the data for the two waves >>

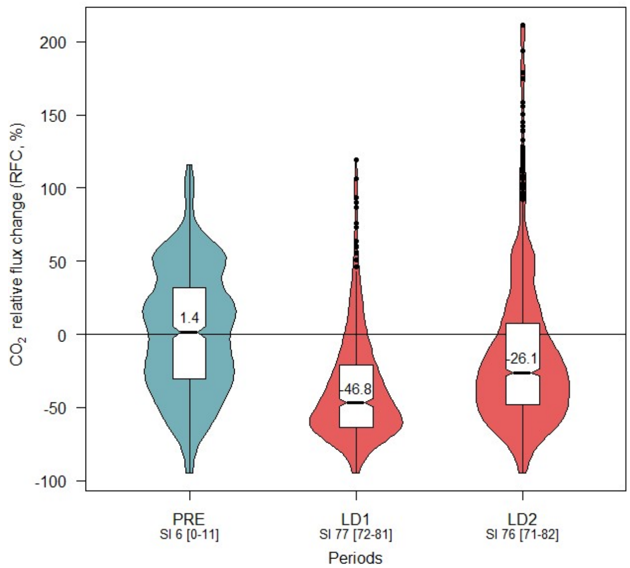
CO_2 flux relative change and restrictions - 2



METROLOGY FOR **CLIMATE ACTION** 26-30 SEPTEMBER 2022

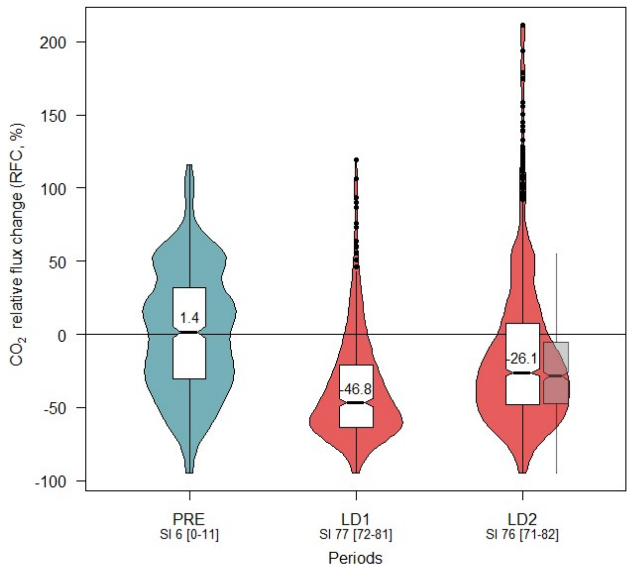
We see that, in general during the second wave the restriction effect was weaker.
Beside to some cities where this effect seems to be similar (e.g. Innsbruck, Berlin-TUCC, Heraklion, Amsterdam), there are cities were it is clearly minor if not vanishes completely (e.g. Vienna or Berlin-ROTH) >>

RFC: 1st and 2nd lockdown differences

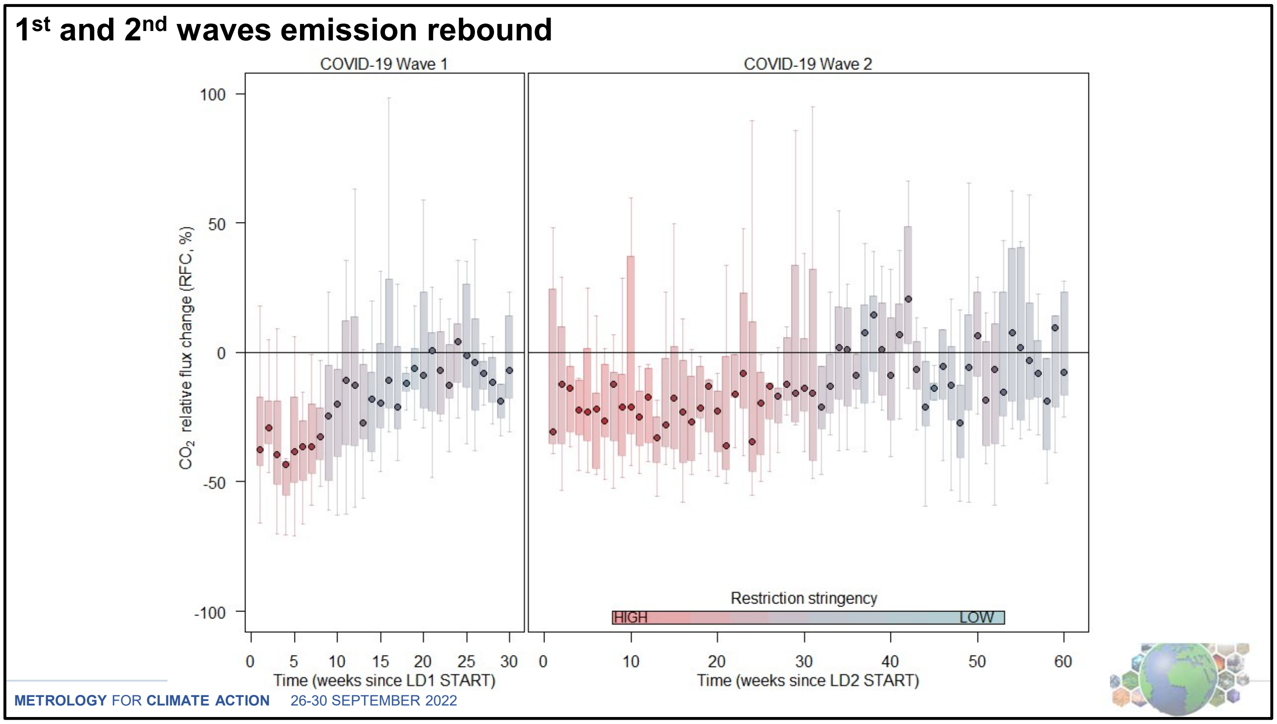


To quantify the lockdown effects on the emissions, I report here the average emission reductions during the 1st and 2nd wave.
Considering all the cities together, despite a very similar stringency range, the reduction during the 1st lockdown (47%) was almost the double than during the 2nd (26%)
It is worth to note however, that the 2nd lockdown lasted in general far more then the first.
But >>

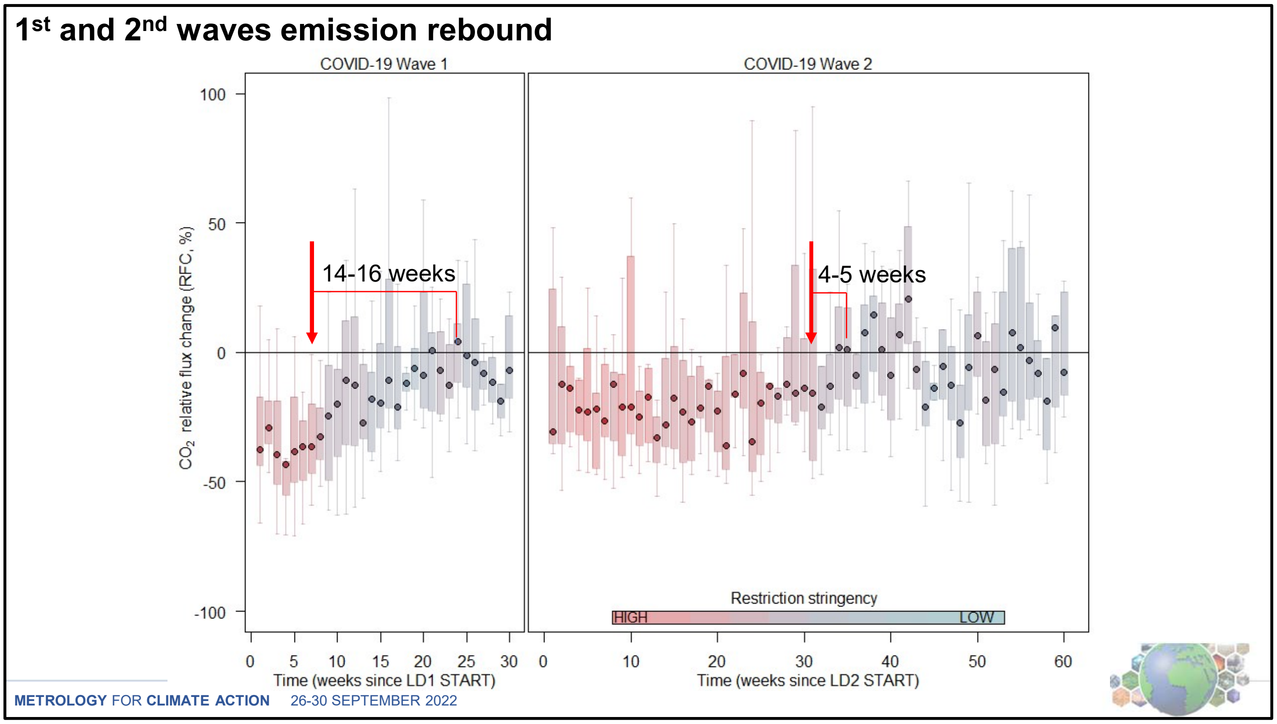
RFC: 1st and 2nd lockdown differences



Even if we consider the same number of days starting from the beginning of the 2nd lockdown, the picture do not change.
And what about the days after the end of the lockdowns? >>

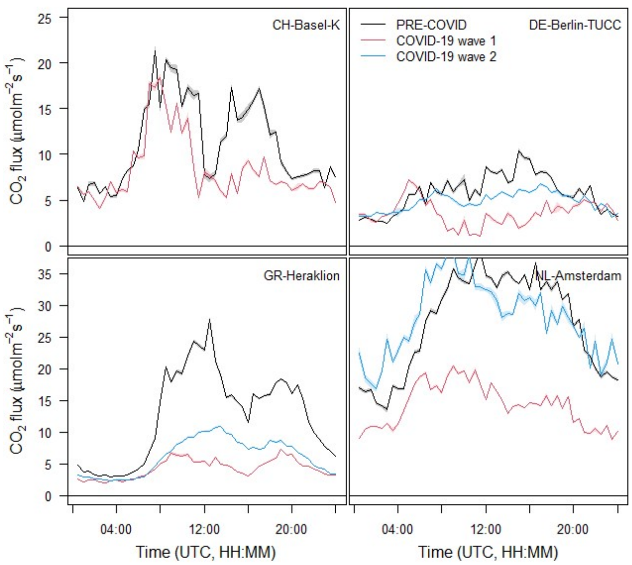


If we consider the weeks following the beginning of the two lockdowns, also putting into relation the average CO2 reduction and the stringency levels, we first see the different duration of the severe restrictions, but also >>



That during the first wave, emissions starting to approach usual values after 14-16 weeks from the lockdown END, while in the second wave it took only 4-5 weeks to return to pre-pandemic levels. >>

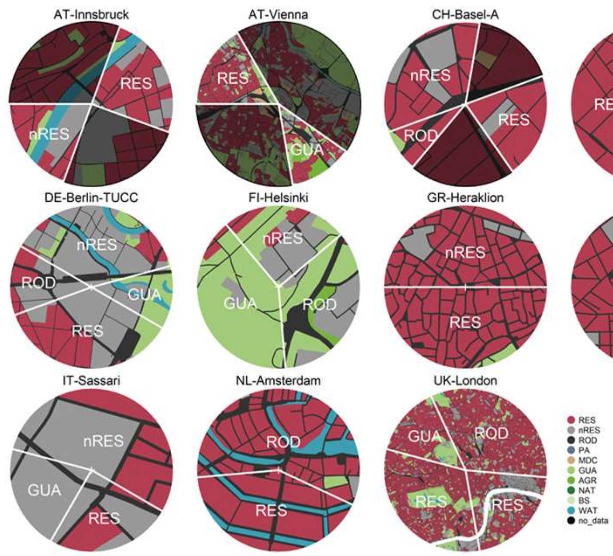
Sub-daily resolution analysis



METROLOGY FOR CLIMATE ACTION 26-30 SEPTEMBER 2022

However, our data allows us to go to a greater level of detail. For example, we can go to a sub-daily resolution and analyse how the CO2 diel fluxes trend changed.
Considering the magnitudes, we still see the differences among lockdown 1 and 2 (with fluxes in LD2 being higher) …
And considering the diel trend we can see how the typical cycled changed, denoting the characteristics of each urban environment.
For example …
>>

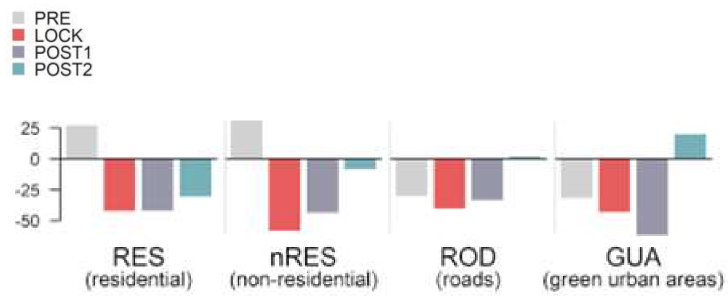
Spatial analysis



METROLOGY FOR CLIMATE ACTION 26-30 SEPTEMBER 2022

A further level of detail concern the direction from which each 30 minutes fluxes was originated, and the possibility to put it into relation with the characteristics of the underlying surface (source area). We indeed characterized each city by a number of wind sectors, as homogeneous as possible in terms of land cover: we envisaged sector characterized by residential and non-residential building, by roads and by green areas.
By looking at the CO2 emission changes within each sector, we saw foe example that

Spatial analysis



Although the sectors which experienced the higher reductions were those characterised by non-residential building and roads, also in the residential sectors the reduction was substantial, meaning that the potential increase in emissions due to the fact that people stayed at home for days (and therefore there was an increase in the use of fossil fuels for heating and cooking and also a concentration of human respiration) was not enough to compensate for the reduction in emissions due to the stop of the circulation of cars and people.

Conclusions

- CO_2 emissions were significantly reduced during the strictest lockdown measures: reductions during the first lockdown were higher than those during the second lockdown.
- Reductions during daytime, principally as a consequence of reductions in vehicular traffic: emissions related to home confinement did not increase enough to compensate reductions.
- Emissions rebounded to previous levels once restrictions were eased in the following months: the rebound after the first lockdown was faster than after the second lockdown.
- Advantages of monitoring networks (e.g. ICOS, www.icos-ri.eu)

So, going to the conclusions, we saw that ….

THANK YOU

Nicolini et al., 2022 STOTEN

Acknowledgements
CoCo2 Project
CoCO2 Prototype system for a Copernicus CO_2 service
ICOS Cities PAUL Project
ICOS Cities