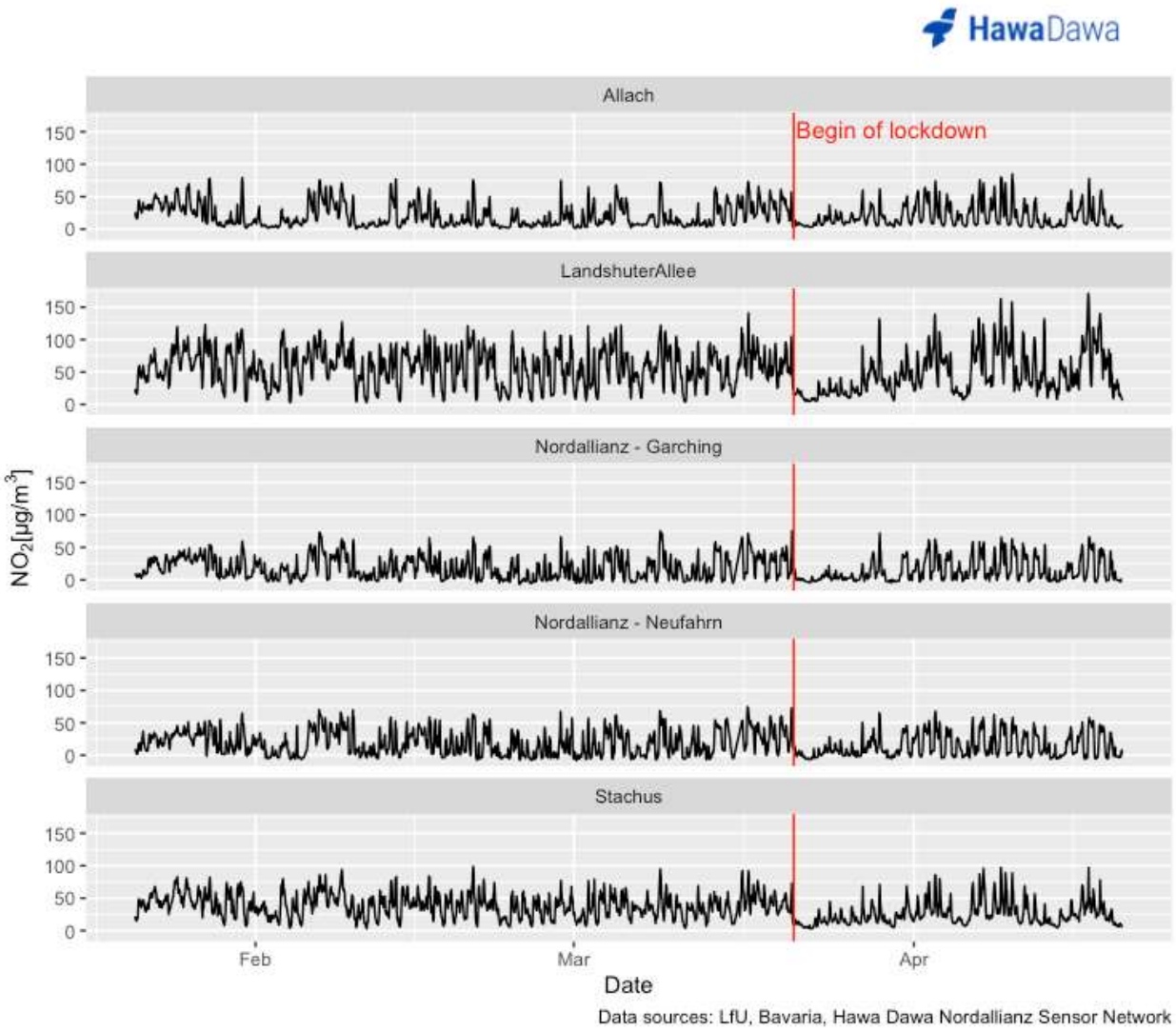
NO_2 Concentrations during the Lockdown in Munich

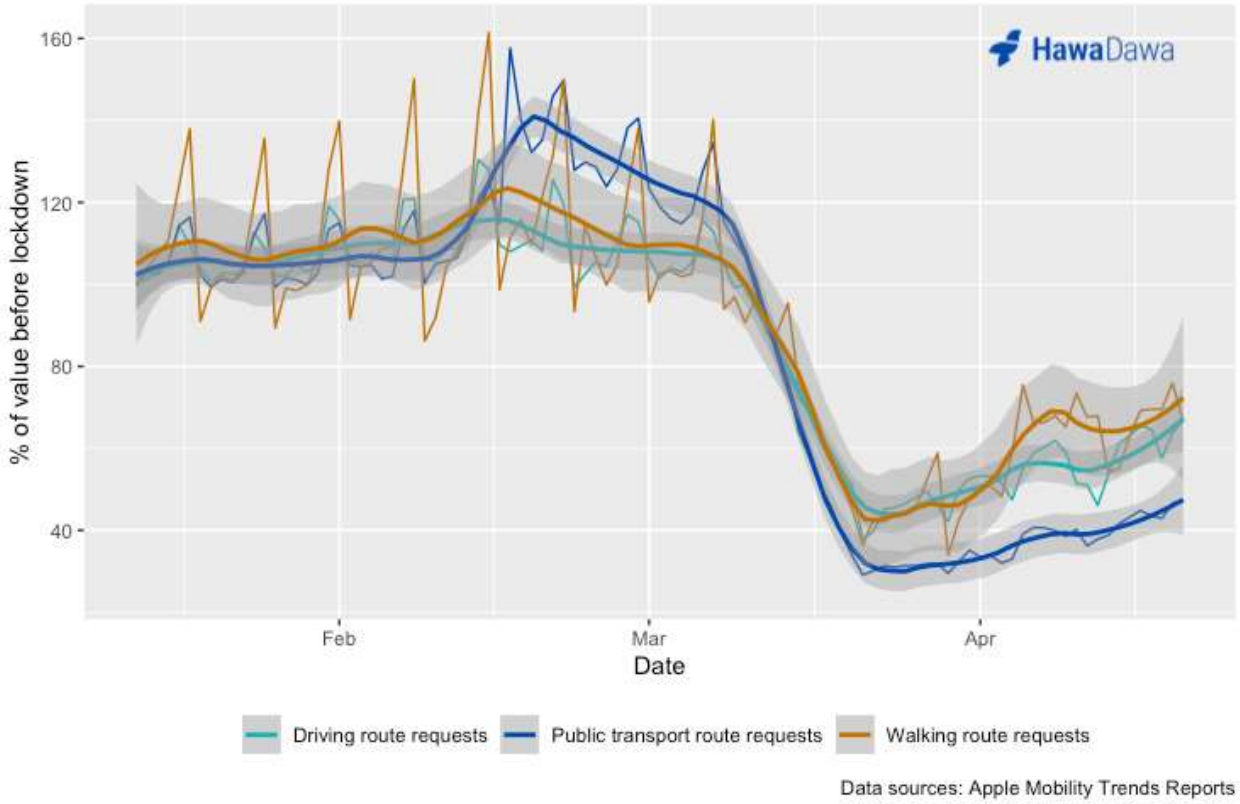
Dr. Birgit Fullerton, April 24, 2020

I have recently heard people uttering disappointment regarding the rather small effect they have observed at official measurement stations in Munich during the time of the lockdown due to the coronavirus. Looking at the raw hourly measurement traces at different locations in and around Munich, it looks like this:



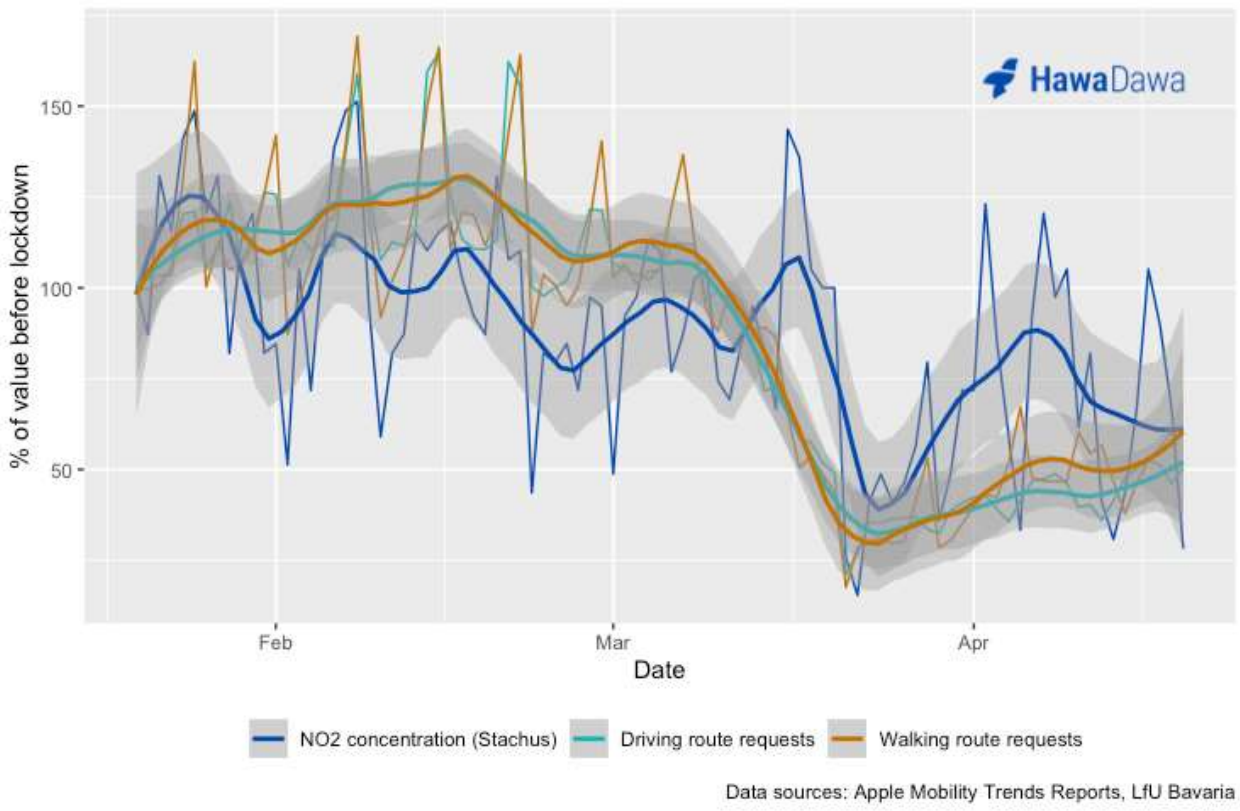
We can see a very clear drop during the initial phase of the lockdown, with concentrations coming up again after that. So yes, it's not that all car emissions have been removed from the city. After maybe a short moment of initial shock, people are still driving, and some people might have even switched to the car to avoid public transport. This hypothesis is also supported by Apple's mobility data, which keeps track of how often people are asking for routes for different modes of transport.

Here we have a plot of the data for Germany. It shows the relative change in route requests compared to how it was before the lockdown (January 13th = 100%).

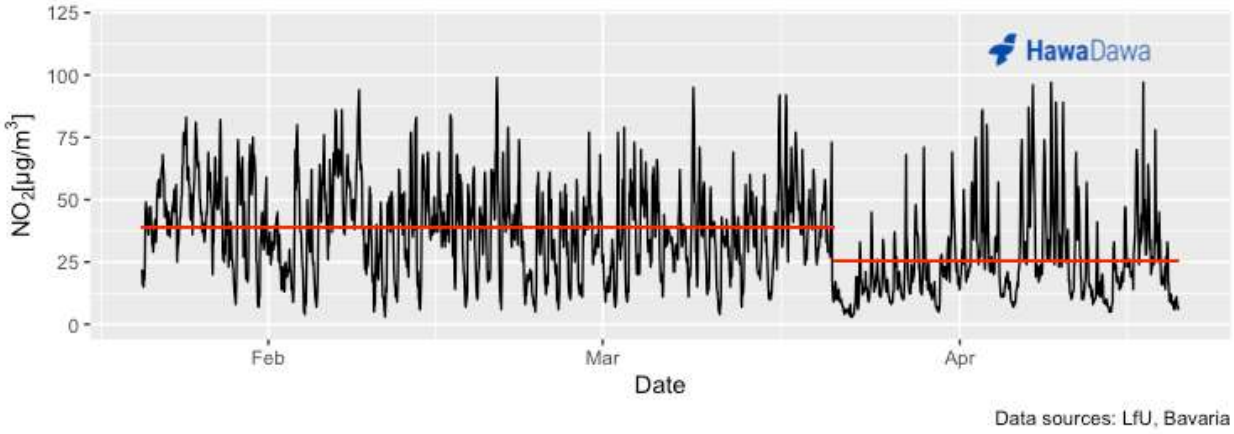


We can see that the number of route requests drastically drops after the beginning of the lockdown, but then starts to increase again during the lockdown period. Furthermore, public transport requests see the largest drop, supporting the idea that people especially avoided using public transport.

The next figure shows mobility data for Munich (data on public transport requests were not available there) together with the change of the NO_2 concentrations measured at Stachus (a place in the center of Munich). The change in NO_2 concentrations does not look as drastic as for the mobility data, however we have to keep in mind that the data from Apple does not show actual mobility but the requests for routes - people's trips to go grocery shopping, to work or other familiar places are certainly not captured in here, so the actual drop in people's mobility is expected to be much smaller than this data suggests. Furthermore, the data obviously only represents a non-random sample (Apple users) of all people moving in the city.



However, just having a quick look at the time trends of measurement stations might not give a clear idea about how large of an effect we are really talking about here, especially since concentrations of air pollutants are also strongly affected by current weather conditions. So we decided to take a slightly deeper look. Let's first actually calculate the mean concentration over the period before the lockdown and during the lockdown (shown as horizontal lines in the figure below, here for Stachus). In the table, we give the averages for a selection of locations in and around Munich. At every station, apart from Andechs (in the Bavarian countryside), we do see a reduction of the average NO_2 concentration. At measurement locations in the center of the city, this absolute difference is much larger compared to measurements taken further out of the city; in Andechs, which is often used to have an idea of the background NO_2 concentration around Munich, the average concentration remains basically the same.



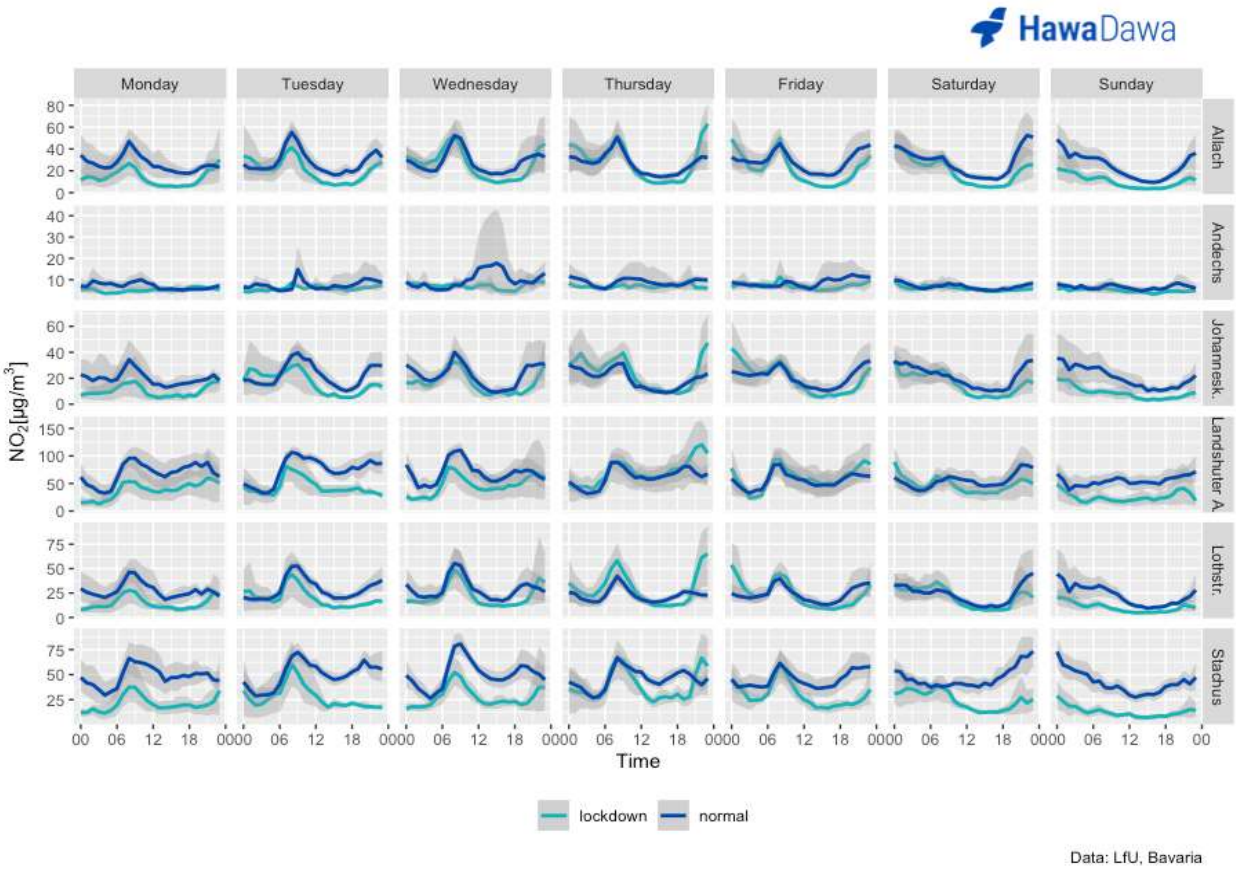
Measurement location	Average NO_2 concentration before lockdown [µg/m^3] (2020-01-21 - 2020-03-20)	Average NO_2 concentration during lockdown [µg/m^3] (2020-03-21 - 2020-04-20)
Allach	21	20
Andechs	6	6
Johanneskirchen	18	16
Munich, Lothstr.	27	20
Munich, Landshuter Allee	58	47
Munich, Stachus	39	25
Nordallianz - Garching	19	15
Nordallianz - Neufahrn	19	14

However, just looking at the time before and during the lockdown could also be misleading, as mentioned before, the weather conditions might change and we are after all comparing data from different times of the year. Alternatively, we could also look at the data from the same time of the year but from previous years (here: 2018 and 2019). The table below compares the average NO_2 concentration of the period March 21st to April 20th from the years 2018 and 2019 to the same period in 2020. We restrict our analysis to the measurement stations of the LfU as our devices in the Nordallianz area were not yet installed back then. We see the same pattern - stronger absolute reductions in the city center compared to locations outside of the city.

Measurement location	Average NO_2 concentration under normal conditions [µg/m^3] (2018/19-03-21 - 2020-04-20)	Average NO_2 concentration during lockdown [µg/m^3] (2020-03-21 - 2020-04-20)

Allach	27	20
Andechs	8	6
Johanneskirchen	21	16
Munich, Lothstr.	26	20
Munich, Landshuter Allee	63	47
Munich, Stachus	47	25

We can also have a look at whether the lockdown effect varies depending on the day of the week. In the next figure, we plotted the average daily curves for different weekdays during the lockdown period in 2020 compared to the same time period in 2018 and 2019. On most weekdays we do see lower concentrations during the lockdown, especially strong effects can be seen at Stachus (a central location with numerous shops and restaurants).



Also, we can see a very large reduction in NO_2 concentrations during the night from Saturday to Sunday, which is most likely due to people not being allowed to go out to restaurants, bars, clubs or the cinema. The grey area around the curves indicates the amount of variability across averaged measurements - for example, the peak on Wednesday during normal conditions is most likely the result of one Wednesday at which the concentrations for whatever reasons showed a high peak at this location. This variability can be the result of unusual events but also of changes in the weather conditions.

Using statistical models, we can control for changes in weather parameters: we performed a regression analysis that in addition to the factor lockdown, included other variables that might have also influenced NO2 concentrations, but are not relevant to our question of how much of an effect the lockdown had on daily NO2 pollution. We ran the model first without and then with control for different weather parameters (such as wind speed, humidity and precipitation).

Controlling for weather conditions, we can observe an average reduction of 13µg/m^3 across all measurement stations during the lockdown. Looking at individual stations the difference is statistically significant for all stations apart from Andechs.

At high traffic locations (Landshuter Allee, Stachus) the lockdown is associated with an average daily NO_2 reduction of 21 µg/m^3 after controlling for different weather parameters. At locations with less traffic outside of the city centre (Allach, Johanneskirchen), the reduction lies at around 9µg/m^3. If we control for the weather, we come to very similar estimates no matter whether we compare the lockdown period with the previous two years (numbers reported above) or whether we compare the period before the lockdown with the time during the lockdown (NO_2-concentration reduction during lockdown = 13µg/m^3 across all stations, 24 µg/m^3 for high traffic stations and 7µg/m^3 at stations outside of the city centre with less traffic). However, if we compare the periods before and after lockdown from this year, we saw that controlling for weather in the models made a much larger difference than when we compared data from the same season from different years, which emphasizes the importance of including weather data when comparing air pollution from two different time periods of the year.

In conclusion, we do see a substantial reduction in daily NO_2 concentrations associated with the lockdown, down to roughly 55% of the concentrations we would usually expect to see at high traffic locations in the centre of the city and down to roughly 70% at locations outside of the city centre. In the countryside, we see no change in the background concentration of NO_2.