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Estimations of the NO_x emissions, NO_2 lifetime and their temporal variation using satellite observations over UK cities

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Context

- **Case study in 2019**: “business as usual” year (before pandemic + no exceptional meteorological event)

- In the UK, **33 zones exceeded the 40 µg/m³ annual limit** of NO_2 concentrations in 2019

- **World Health Organisation** have issued new guideline in air quality levels to protect the health of populations:

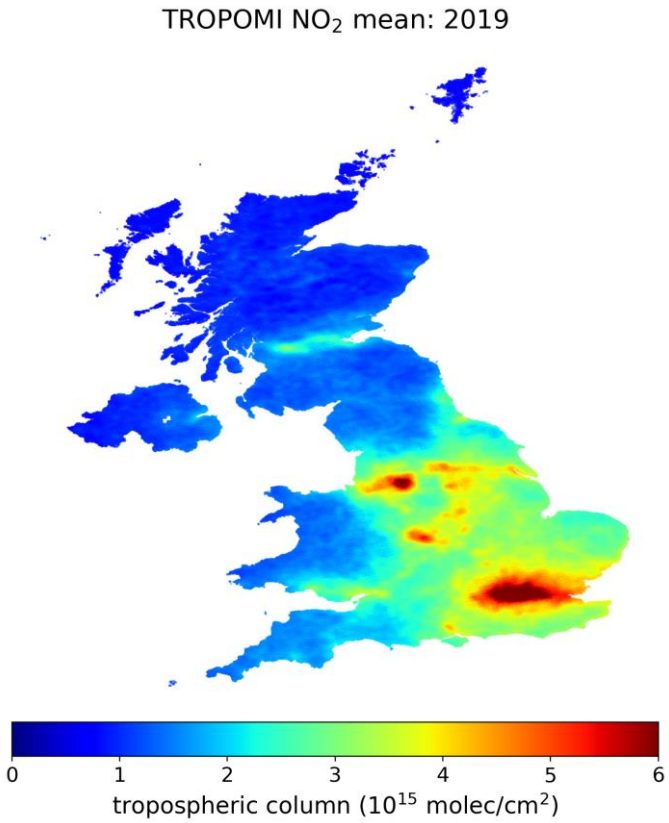
10 µg/m³ as an NO_2 annual average

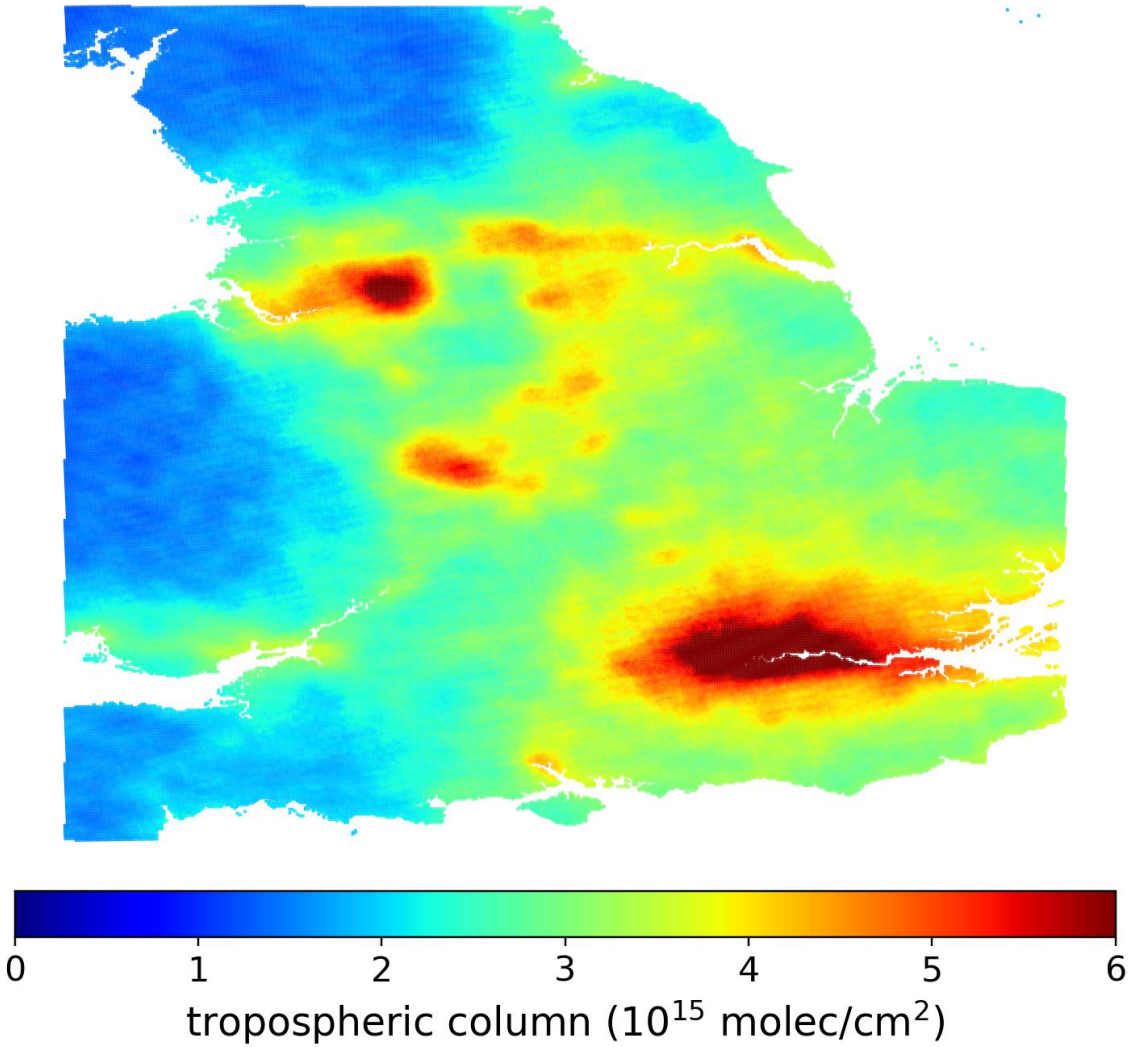
- The knowledge of the emissions is crucial to better model the NO_2 concentrations, and to implement mitigation strategies.

NO_2 in the UK

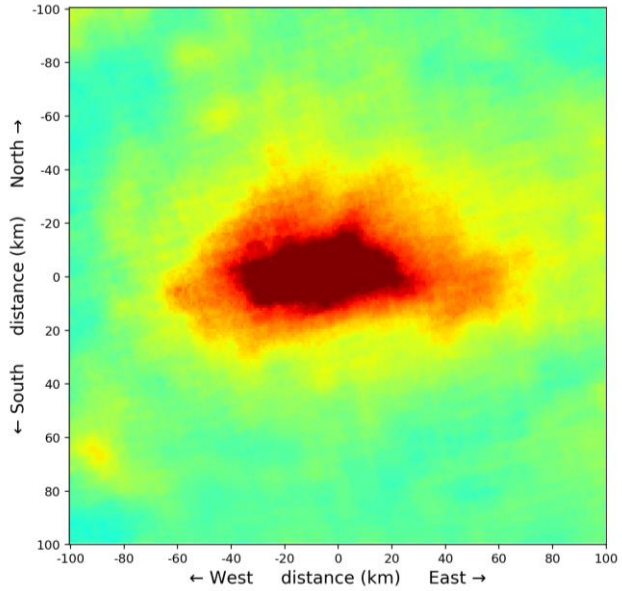
Annual mean in 2019

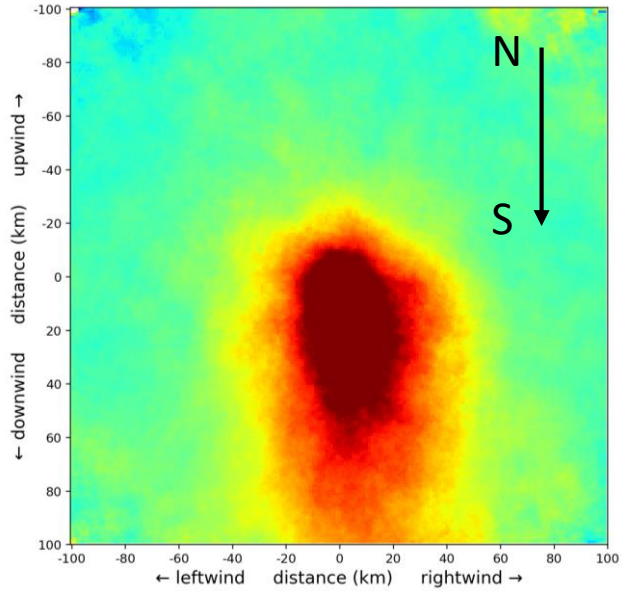
Map calculated at 1 km × 1km resolution
Tropospheric column with a quality flag > 0.75 (OFFL product)

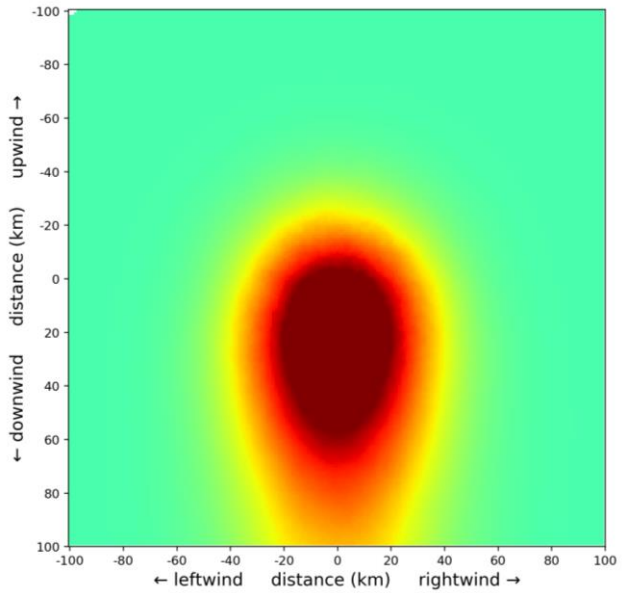




Method: example in London







1) Isolate your NO_2 source (hotspot)

2) The ECMWF* wind fields integrated in the 1000-900 hPa layers are collocated in space and time to the TROPOMI observations

*ECMWF = European Centre for Medium-Range Weather Forecasts

Use of ERA5 reanalysis hourly data with a horizontal resolution of 0.25° × 0.25°.

3) Rotate each observation using ECMWF wind information in a common direction (e.g. Pommier et al. (GRL, 2013) ; Valin et al. (GRL, 2013))

~ same observation if the wind constantly blows in the same direction

4) Fit the distribution with an exponential modified Gaussian function (e.g. Fioletov et al. (JGR, 2015); Dammers et al. (ACP, 2019))

→ mean NO_2 emission rate and lifetime are calculated

1.32 NO_x/NO_2 ratio used for the conversion (e.g. Ialongo et al. Atmos. Env., 2021, Goldberg et al. ACP 2022)

Results: annual estimates

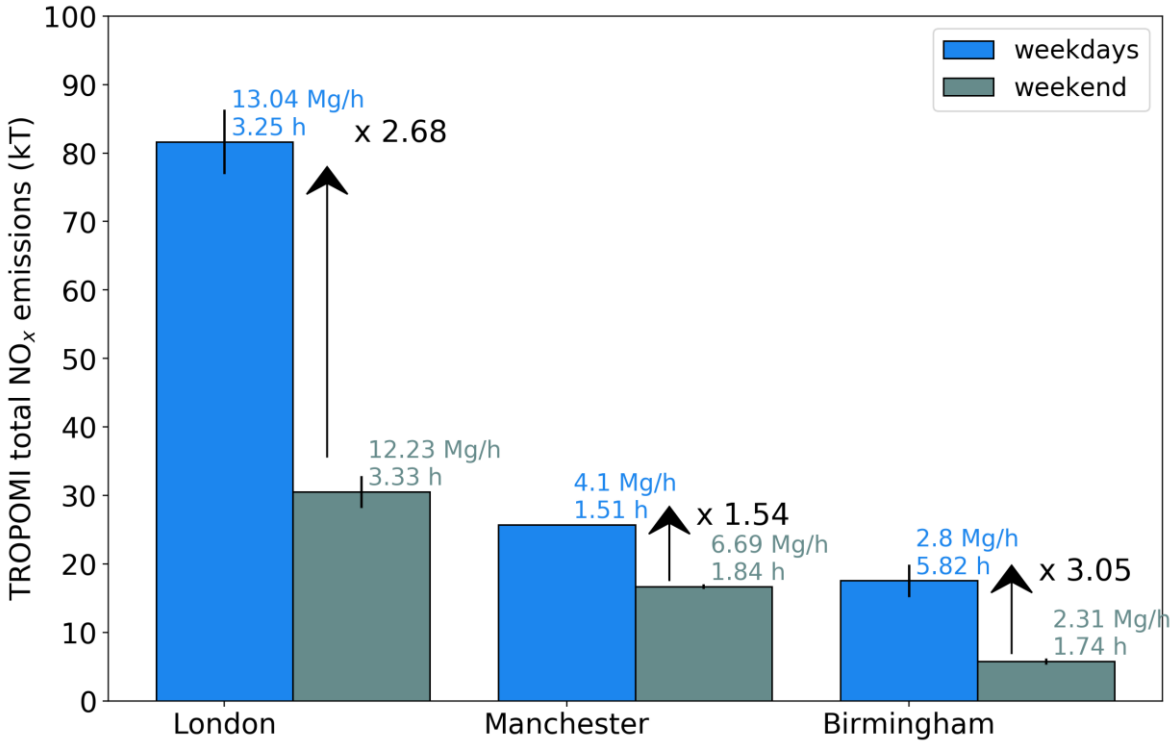
- For the same size of area, Manchester has a larger annual emission but a lower lifetime than Birmingham.
- Better agreement with the National Atmospheric Emission Inventory compared to a previous study for these conurbations.

Pope et al. (ACP, 2022)

urban area (size of the area)	number of days of observations	Mean NO_2 lifetime (h)	Total NO_x emission estimates (kT)	Comparison with the NAEI* NO_x	Comparison with the NAEI
London (100 km × 100 km)	254	3.2 ± 0.3	113 ± 6	+18%	+55%
Manchester (60 km × 60 km)	199	1.6 ± 0.02	37 ± 0.3	+6%	+105%
Birmingham (60 km × 60 km)	212	5.7 ± 0.65	22 ± 3	-33%	+72%

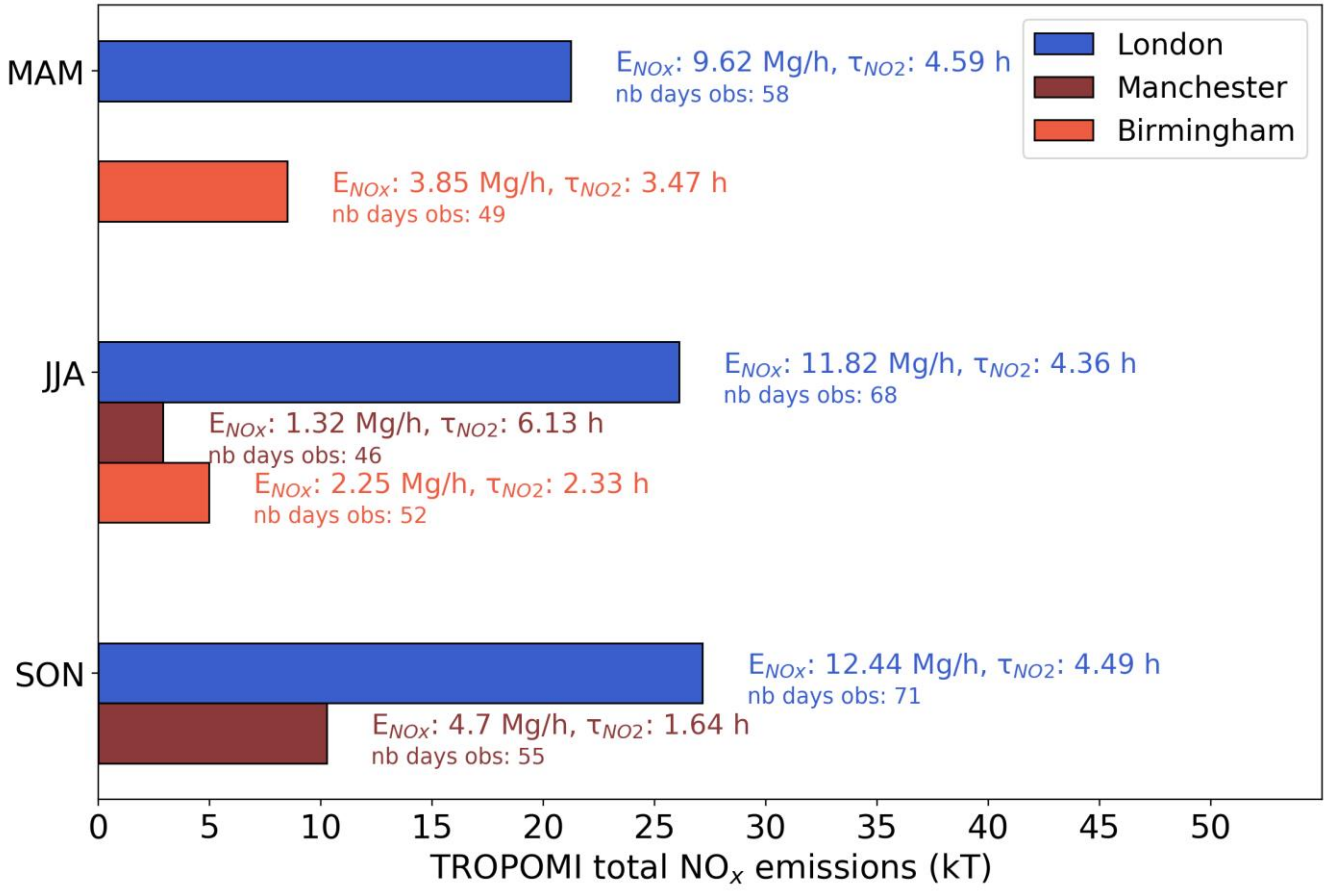
* **National Atmospheric Emission Inventory (NAEI):** *Data available at https://naei.beis.gov.uk/data/*

Results: weekdays-weekend estimates



- Larger difference (ratio) in total NO_x emission in Birmingham
- Mean NO_x emission rate larger in weekend than in weekdays in Manchester (relatively similar in London and Birmingham)
- Larger difference in mean NO_2 lifetime in Birmingham (5.8h weekdays vs 1.7h in weekend)

Results: seasonal estimates



MAM: March-April-May
JJA: June-July-August
SON: September-October-November

- Fit does not work for all seasons and not in winter (even if observations of all seasons are used in the annual and weekend-weekdays calculations)
- Summer emissions are the lowest in Manchester and Birmingham → ~50% of the annual emissions are from the car traffic in these areas (source: NAEI). Does it correspond to a reduction in the traffic?
- Surprisingly, Manchester has a mean NO_2 lifetime ~4 times larger in summer (6.13h) than in autumn (1.64h) [usually, mid-latitudes cities are characterised with a lower lifetime in summer]

Results: implication on mitigation

- London & Birmingham: policies could target the weekday emissions for all seasons. The seasonal variation is less pronounced and weekday emissions are much greater than weekend.

- Manchester: could benefit an improved air quality with measures on weekend emissions since the emission rate and the lifetime are larger during the weekends.

- Manchester :

- Targeting the summer emissions might help to reduce the number of consecutive hours of exposure to NO_2 exceedance due to the longer NO_2 lifetime,
- The reduction of autumnal emissions might decrease the NO_2 concentrations since the mean NO_x emission rate is higher.

Possibility to improve the calculations

Few ideas:

- Current NO_x emission relies on a prescribed NO_x/NO_2 ratio → convert the NO_2 values into NO_x prior the fitting procedure (e.g. Lange et al., ACP 2022)
- Take into account the temporal variations in wind fields (Liu et al., ACP 2022)
- Using an algorithm for multi-sources, isolating the impact of surrounding sources (Fioletov et al., ACP 2022) → Vitali Fioletov's presentation yesterday
- Using more spatially resolved wind fields (currently ERA5 at 0.25°× 0.25°)

To continue on this topic…

More details are given in:

"Estimations of the NO_x emissions, NO_2 lifetime and their temporal variation over three British urbanised regions in 2019 using the TROPOMI NO_2 observations", *under review in Environmental Science: Atmospheres*

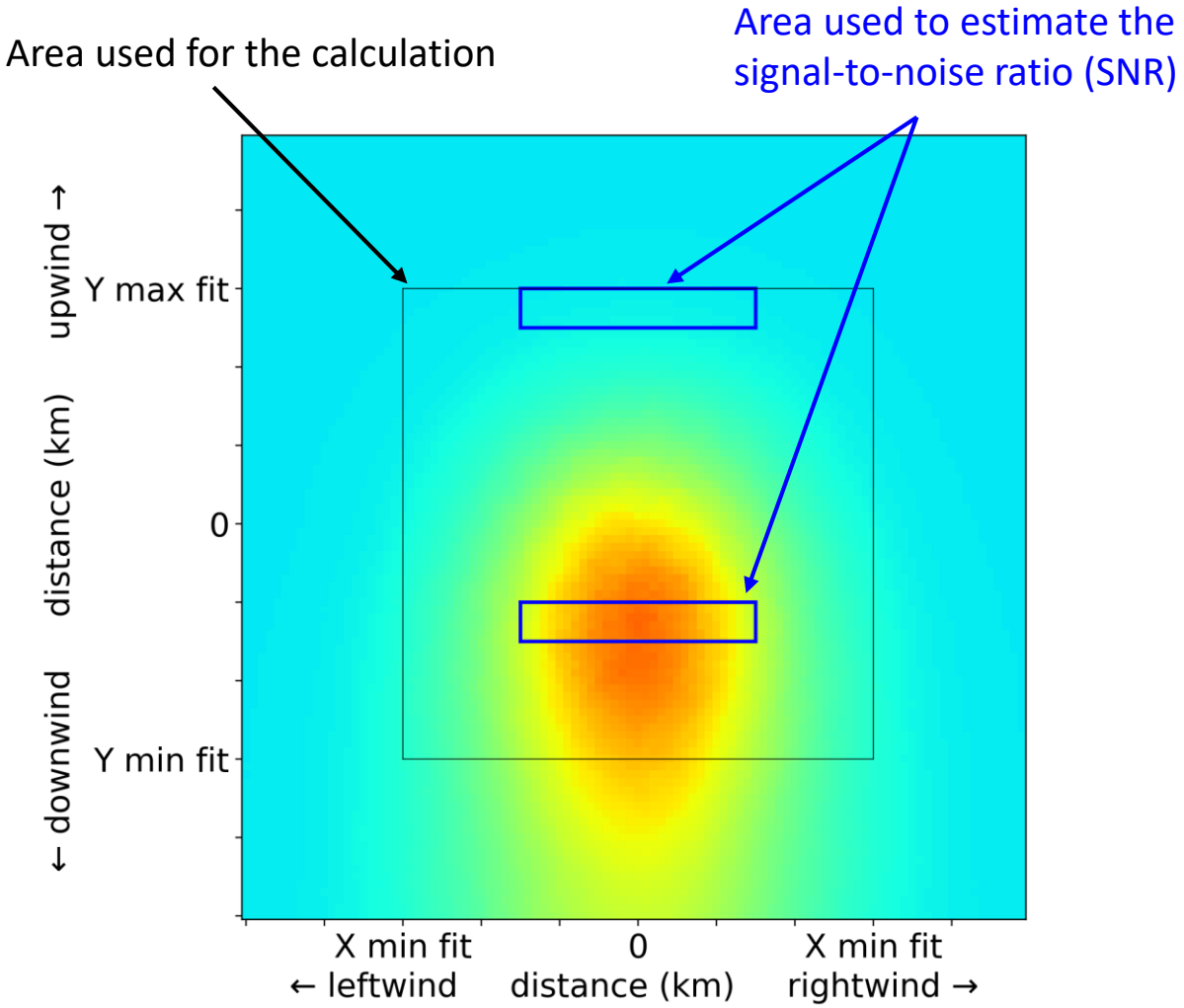
<u>For example:</u>

- Discussion on the annual estimates
- Sensitivity tests
- Selection of the cities
- Etc.

More questions: please contact me at matthieu.pommier@ricardo.com

Additional slide

Method: How to define the regions fit for purpose?



- **Signal-to-noise ratio calculated** as the difference between the mean value in the downwind and upwind areas weighted with their standard deviation
- Only London, Manchester and Birmingham have a large SNR in this first test (e.g. Leeds, Cardiff have a very low SNR)
- This suggests some parts of the UK won't meet the requirement for inventory checking with this method
- Method may be difficult to apply in cities where the SNR is too low (e.g. during low emission episodes → lockdown?)