How did COVID-19 'Lockdown' Policy Impact Ambient Air Quality, Atmospheric Composition and Reactivity in the UK?

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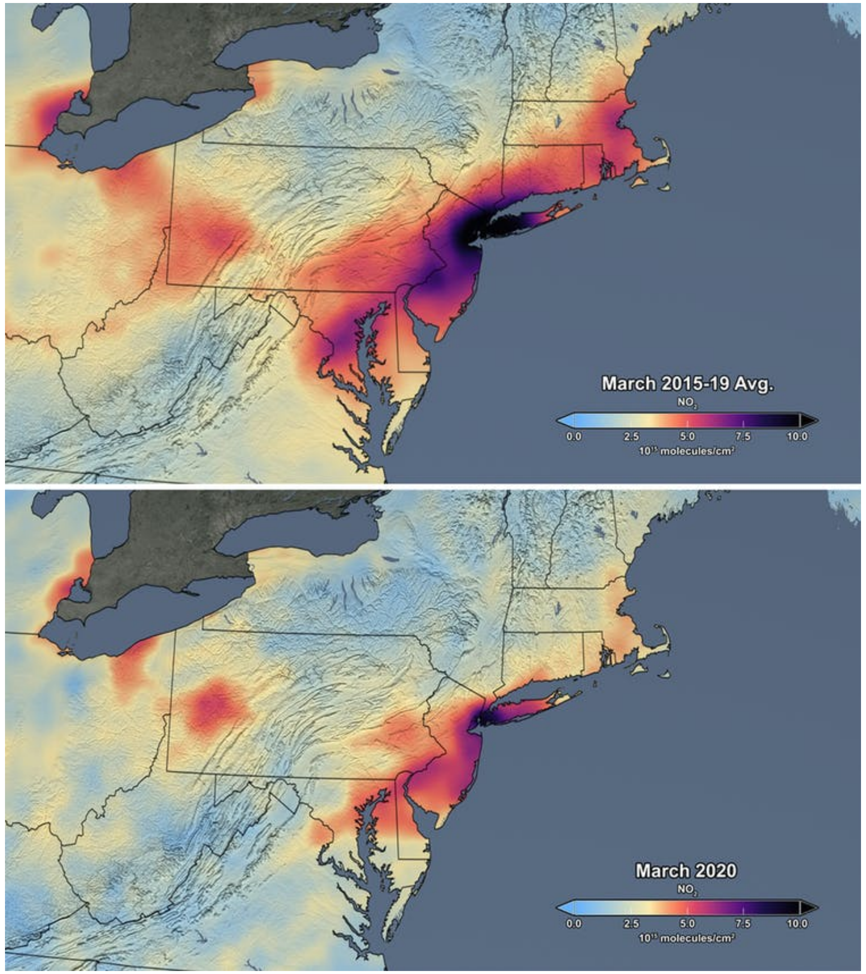
Introduction

Background

- COVID-19 led to reductions in anthropogenic activity and emissions of air pollutants (the ‘anthropause’)
- Early remote sensing showed NO_2 down by ~30% across China; ~40% across central Europe
- Such dramatic, rapid reduction in air pollutants across species emissions spectrum, globally, is entirely unique -> resultant impacts on chemical processes and composition need investigating



EPA-EFE/NASA

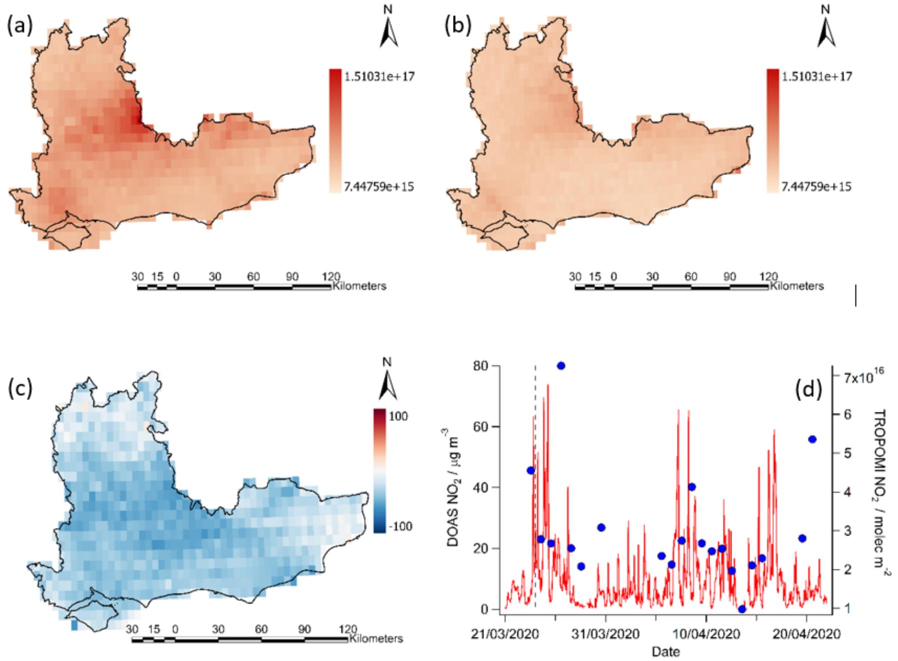
Questions and answering them

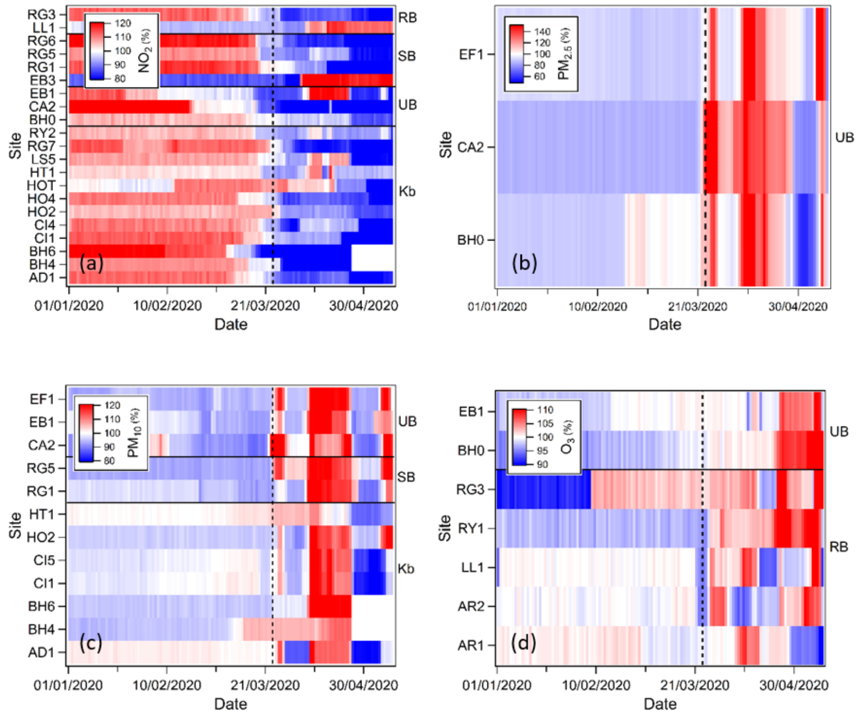
- With reductions in NO_x and poorly characterised changes in VOCs what will be the impact on secondary pollutants, inc. O_3?
- What will be the impact on oxidative capacity?
- Will we experience a shift in size distribution of particulate numbers?
- How will PM composition change?
- Here we aimed to investigate some of these changes in the SE UK

Methods

- SE UK is a strategic location, having largest regional population (9.13m) and located between 2 major air pollution hotspots (London, industrial NWE)
- Our work was based on measurements made by DEFRA's AURN and AHN, Sussex-Air network, TRL sites, Brighton Atmospheric Observatory (BAO) and ESA's Sentinel-5P satellite
- Total of 27 ground stations with a variety of instruments measuring NO_x, O_3, HCHO, HONO, HCs, $PM_{2.5}$ and PM_{10}
- For parts of time-series analyses, data were de-weathered to remove influence of meteorology
- Measurements were supported by 0D box modelling using the MCM mechanisms to investigate changes in chemistry and radicals

Results: Broad regional changes

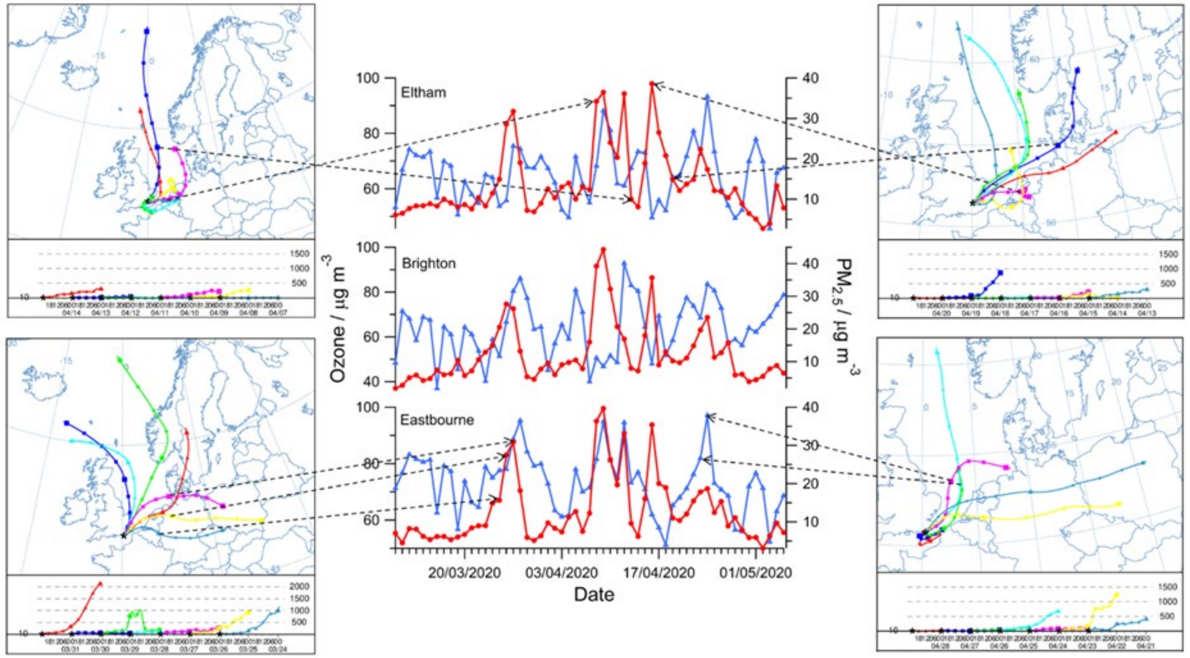


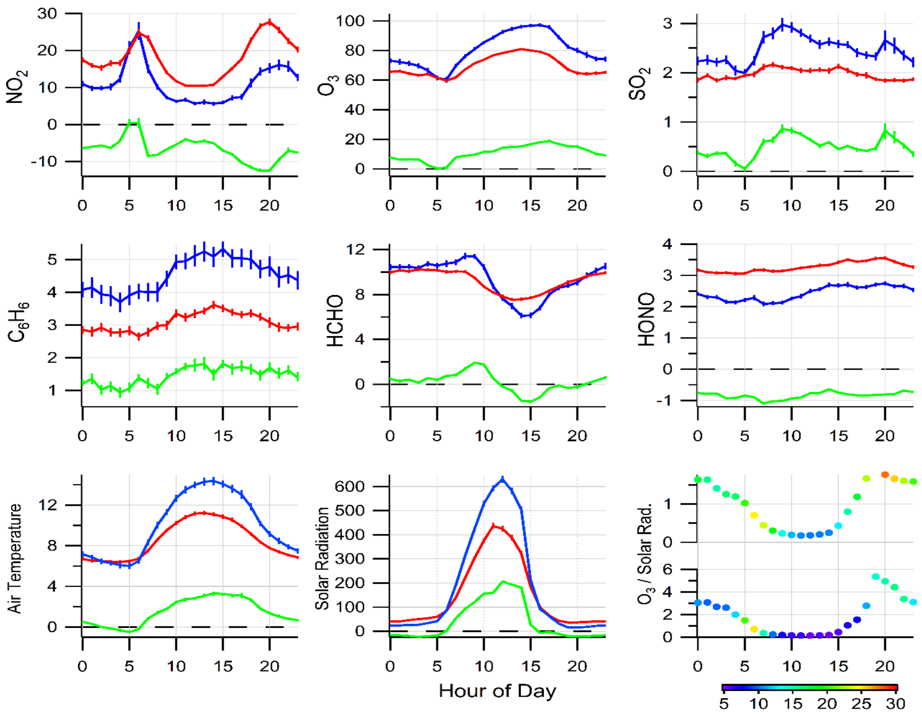


- TROPOMI NO_2 levels presented as significantly lower during lockdown (b) vs. 2019 baseline (a)
- Primary changes in centre of region (c)
- Regional average NO_2 fell by 33%

- Local relative changes in ‘de-weathered’ and absolute NO_2 echoed this finding (a) with Kb, UB, SB, RB levels down 14-38% (wrt 5-yr baseline)
- PM levels (b and c) were variable across sites
- O_3 levels appeared to have increased (d)

Results: Changes in detail

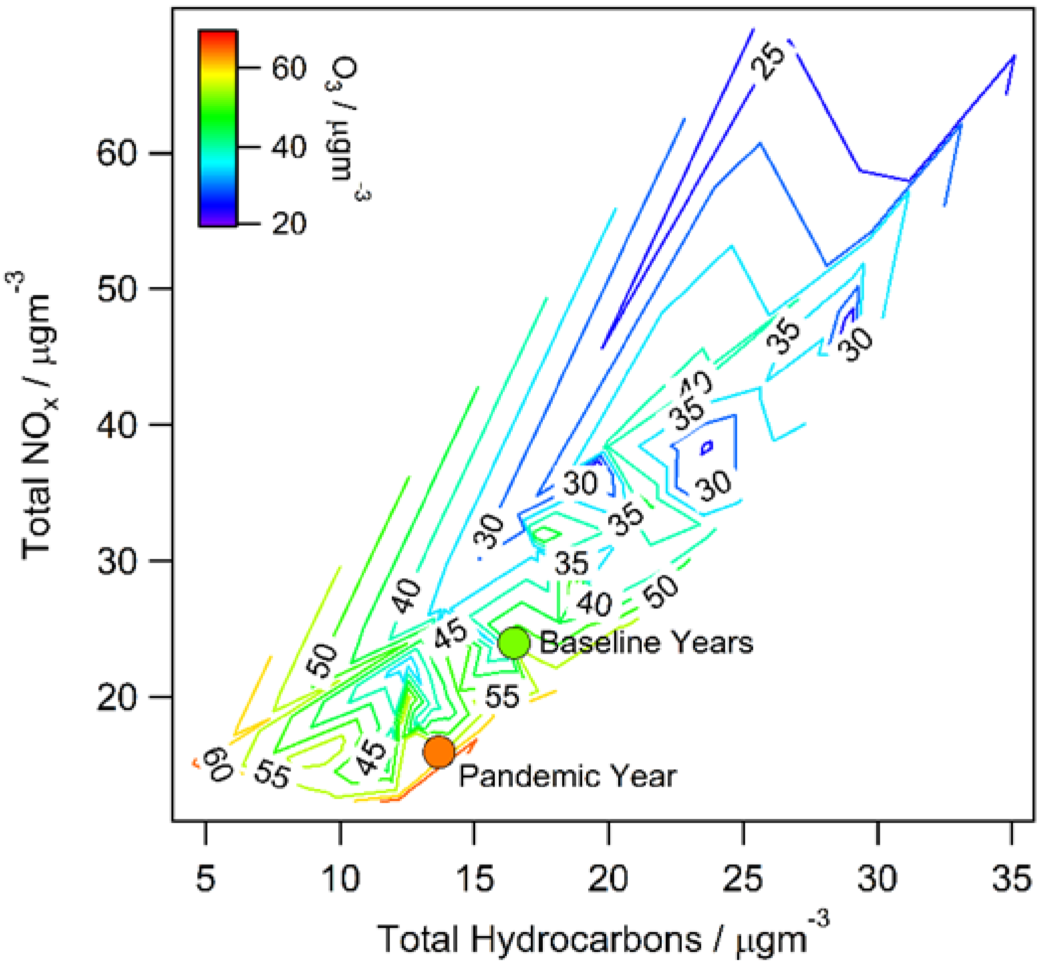




- Daily average $PM_{2.5}$ (red) for Eltham, Brighton, Eastbourne with HYSPLIT modelling helps explain PM behaviour
- Peaks in PM correlate with the timing of mass air movements bringing pollution from North West Europe

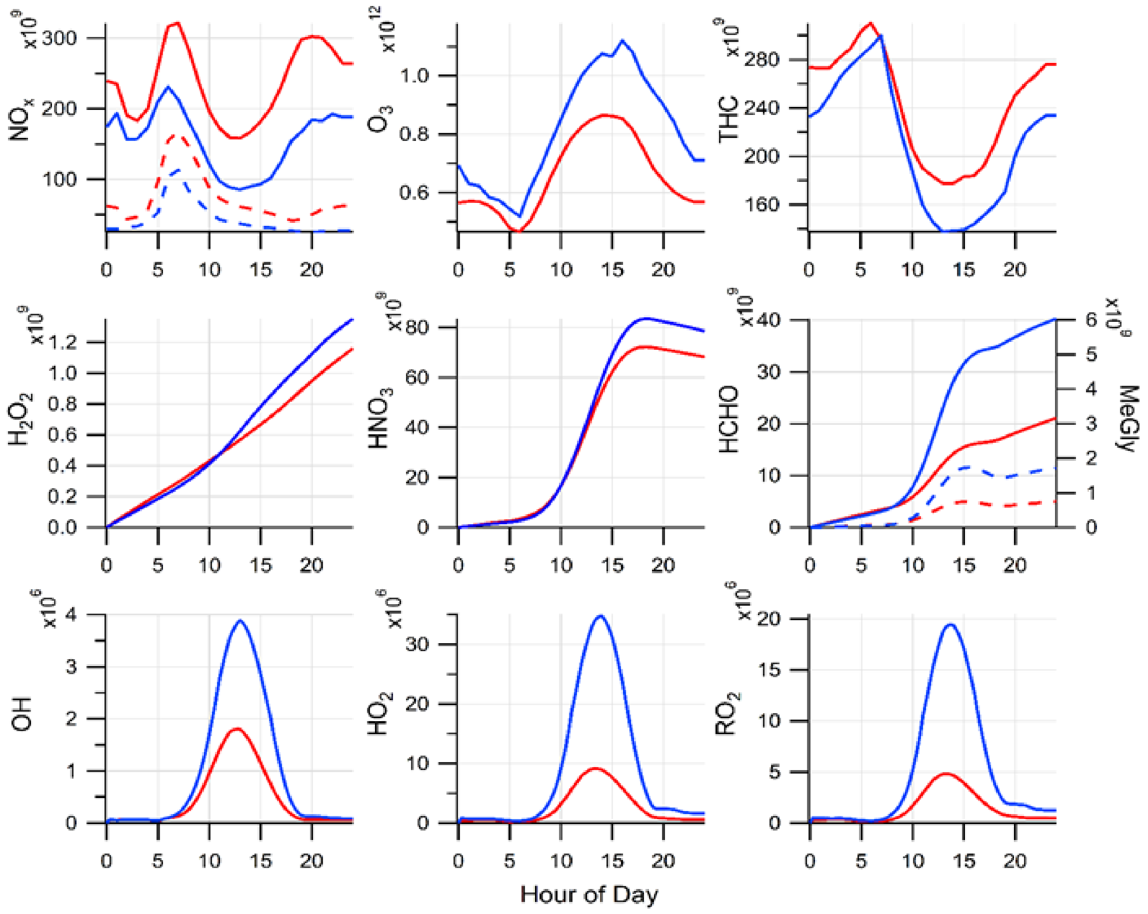
- Average diurnal evolution of trace gases (DOAS) and met. Before (red) and during (blue) lockdown
- Similar daily patterns, but NO_2, HONO - down; O_3 (+15%), SO_2 (+25%), C_6H_6 - up; HCHO - similar; hotter and sunnier

Results: Changes in chemistry



- To investigate the urban O_3 chemistry further we needed HC measurements – Eltham AHN (SB, outer London)
- Eltham: NO_2 = -35%, O_3 = +22%, HCs = -17%
- HCs: Aromatics = -34%, alkanes = -16%, alkenes = -6%
- NO_x-HC-O_3 relationship best visualised using a surface plot (O_3 isopleth)
- Regime: characterised by $[NO_x] > \Sigma[NMHC]$, where higher $[O_3]$ typically results from lower values of both species
- Relative positions of atmospheres before ('Baseline Years') and during lockdown ('Pandemic Year') shown
- Baseline years sit within a HC limited regime
- During lockdown, [NOx] decrease > [NMHC], so NMHC:NOx increased (0.70 to 0.87). In HC limited regime (with actinic flux), this led to increase $[O_3]$

Results: Radicals and oxidative capacity



- Question: with decreased $[NO_x]$ and increased $[O_3]$, what is the effect on radicals and oxidative capacity*?
- HCHO and methyl glyoxal values up during lockdown – more reactive atmosphere?
- Modelled OH, HO_2 and RO_2 higher during lockdown by 109, 245 and 259%
- Shift in partitioning between HO_x/RO_x during lockdown, indicative of increase in forward cycling of OH to HO_2 and RO_2 via CO and RH, and decrease in recycling of HO_2 and RO_2 to OH *via* NO
- Comparing modelled radical recycling to chain termination routes and modelled HO_x:NO_x, simulations suggest branching shifted toward more radical chain cycling/propagation

*The diurnal mean ability of the [troposphere] to oxidise trace compounds

Conclusion

- COVID-19 resulted in emergency policy that reduced certain pollutant emissions very rapidly
- Decline in NO_2 by 14 – 38% in SE owing to a reduction in vehicle traffic by as much as 70%
- But, also concomitant increase in average ambient O_3 concentrations (urban, hydrocarbon limited conditions)
- Under 2020 conditions, model results suggest this led to increased OH, HO_2, RO_2
- This suggests a more complex scenario than originally reported and provides a potential window into a future of reduced NO_x emissions