Exploring seasonality and trends in respiratory diseases across different settings

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This project

- This project will combine mathematical and statistical modelling with data from the UK Health Security Agency to explore the impact of the COVID-19 epidemic on six respiratory diseases: influenza A, influenza B, Respiratory Syncytial Virus (RSV), rhinovirus, parainfluenza and adenovirus.
- Stream A:
  - We will use an established mathematical model calibrated to influenza data until end of 2019, to explore possible influenza A and influenza B epidemic waves that may emerge under different combinations of vaccination effectiveness and background population susceptibility.
  - Initial work has been done and publicly available https://www.medrxiv.org/content/10.1101/2023.01.06.23284264v1 but extensions based on policy questions need to be addressed.
- Stream B:
  - We will use statistical modelling to quantify the changes in each of the six respiratory diseases: influenza A, influenza B, Respiratory Syncytial Virus (RSV), rhinovirus, parainfluenza, adenovirus in the preCOVID-19 period of 2018/2019 and 2019/2020 years, during the COVID-19 seasons of 2020/2021 2021/2022 and over the current 2022/2023 seasons.

Previous work over the last 10 years

➢ Modelling seasonal influenza (2013/2014-now)

- Modelling influenza transmission and interventions. Baguelin M et al. PLoS Comput Biol. 2017 20;13(11):e1005838.
- van Leeuwen E et al. fluEvidenceSynthesis: An R package for evidence synthesis based analysis of epidemiological outbreaks. PLoS Comput Biol. 2017 Nov 20;13(11):e1005838. doi:10.1371/journal.pcbi.1005838.
- Effect of mass paediatric influenza vaccination on existing vaccination programmes in England and Wales. Hodgson et al. Lancet Public Health 2017; 1:e74-81.
- The interplay between population susceptibility and vaccine effectiveness will impact future influenza waves. Panovska-Griffiths, van Leuween et al. https://www.medrxiv.org/content/10.1101/2023.01.06.23284264v1.

➢ Modelling pandemic influenza (2017-2020; 2023)

- Are we prepared for the next influenza pandemic? Lessons from modelling different preparedness policies against four pandemic scenarios. J Theor Biol. (2019) doi: 10.1016/j.jtbi.2019.05.003
- A method for evaluating the cost-benefit of different preparedness planning policies against pandemic influenza. MethodsX (2020). doi: 10.1016/j.mex.2020.100870
- Exploring the role of mass immunisation in influenza pandemic preparedness: A modelling study for the UK context. Vaccine (2020) doi: 10.1016/j.vaccine.2020.06.032.

➢ Modelling COVID-19 with agent-based models (2020-2023)

- Methods of Covasim – PLoS Comp Biol (2021), doi: 10.1101/2020.05.10.20097469
- Modelling TTI and reopening of schools in September 2020 – "effective TTI key to reopening schools" – *Lancet Child & Adolsc Health (2020)*, doi:10.1016/S2352-4642(20)30250-9
- The importance of wearing masks in reopened schools – "masks necessary in schools" –*Sci Rep (2021)* *doi:*10.1038/s41598-021-88075-0
- Modelling TTQ in King Country, USA – *"effective TTQ can control the epidemic"* – Nat Commun (2021). doi: 10.1038/s41467-021-23276-9
- Modelling reopening roadmap at Stage 1 – *"schools can open in March if rest of lockdown stays"* – *JMAA (2021)* *doi:*10.1101/2021.02.07.21251287
- Modelling transmissibility of different SARS-CoV-2 variants in England and impact of different interventions. – *"delay at Step 4 of reopening is necessary to mitigate delta spread"* – Phil Trans Roy Soc A (2022) https://doi.org/10.1098/rsta.2021.0315.

➢ Modelling the seasonality across respiratory diseases (2023-now)

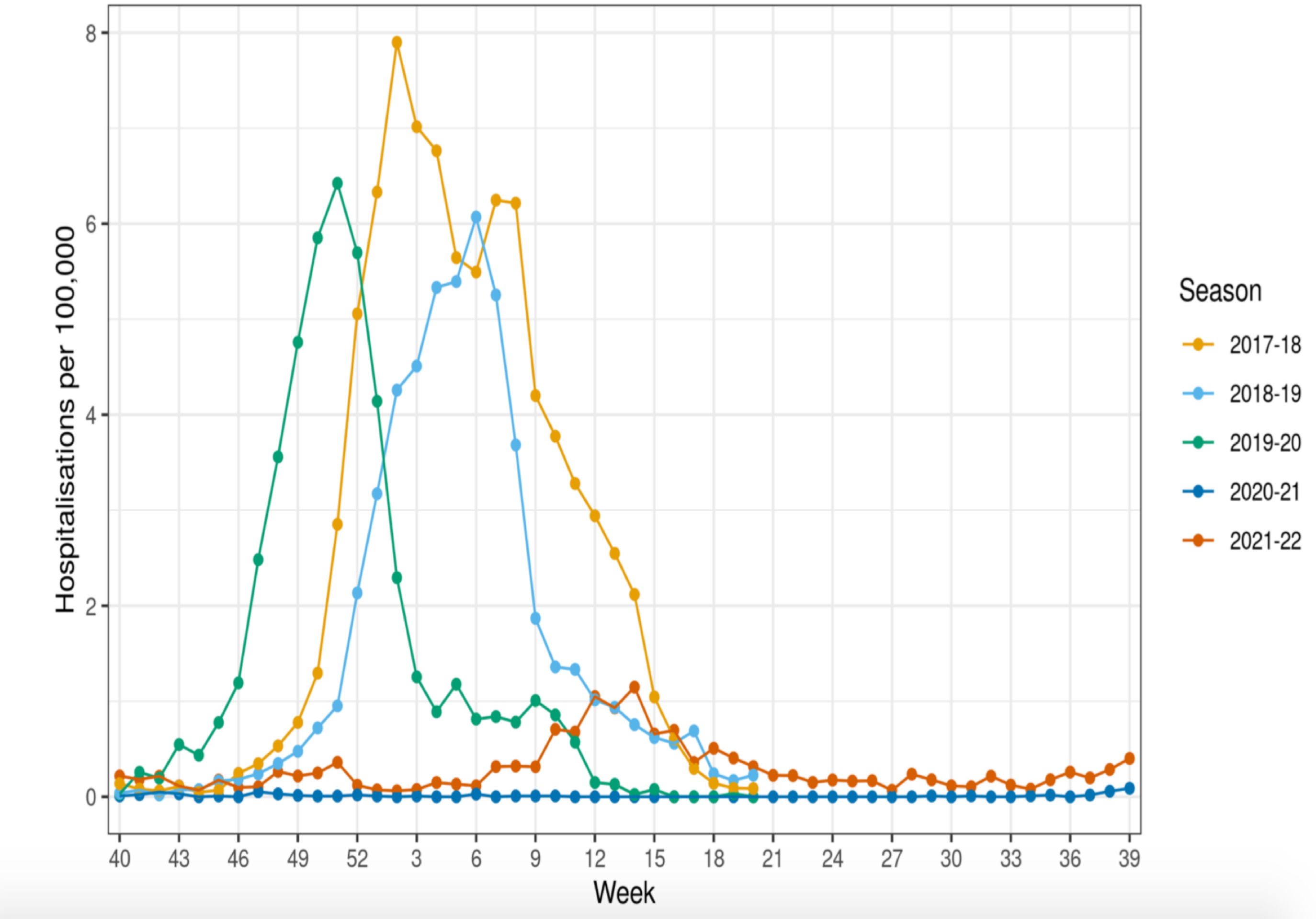
Example of Stream A previous work

The interplay between population susceptibility and vaccine effectiveness will impact future influenza waves

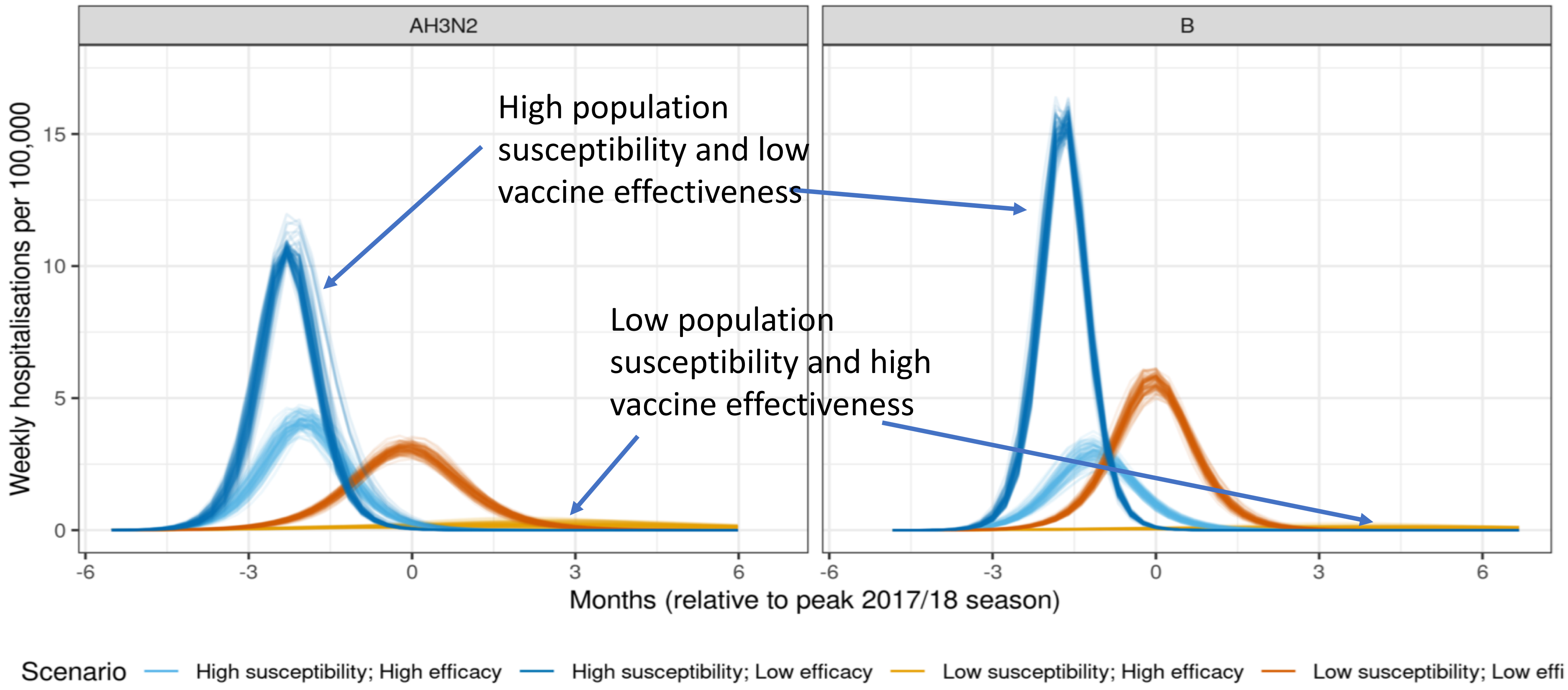
Panovska-Griffiths, van Leeuwen et al.
Epidemics 2023 doi: 10.1016/j.epidem.2023.100709

Historic influenza waves

- In 2017/18 season both AH3N2 and B strains were circulating in significant numbers.
- 2018-19 season was dominated by AH1N1pdm09.
- 2019-20 season was dominated by AH3N2.
- Low influenza levels were present during 2020/21 and 2021/22 seasons.



Different winter influenza waves are possible

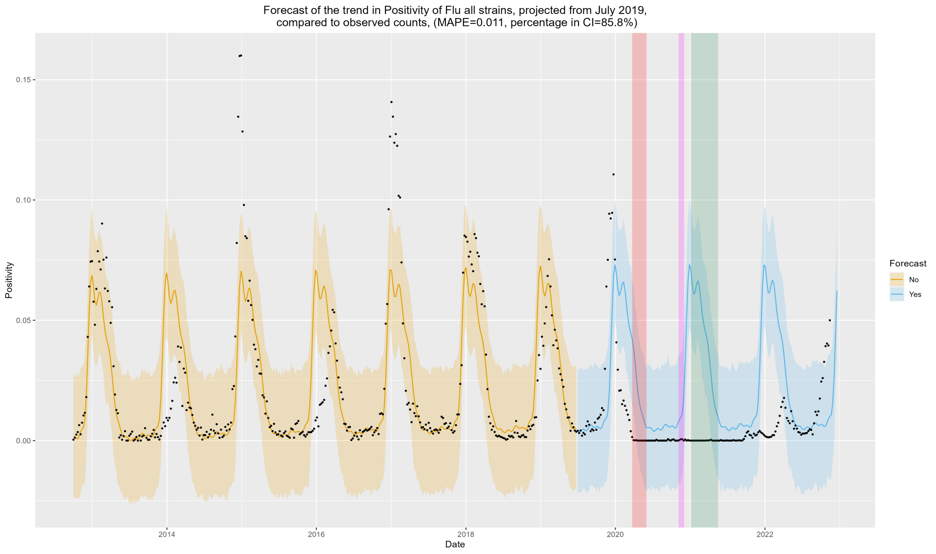


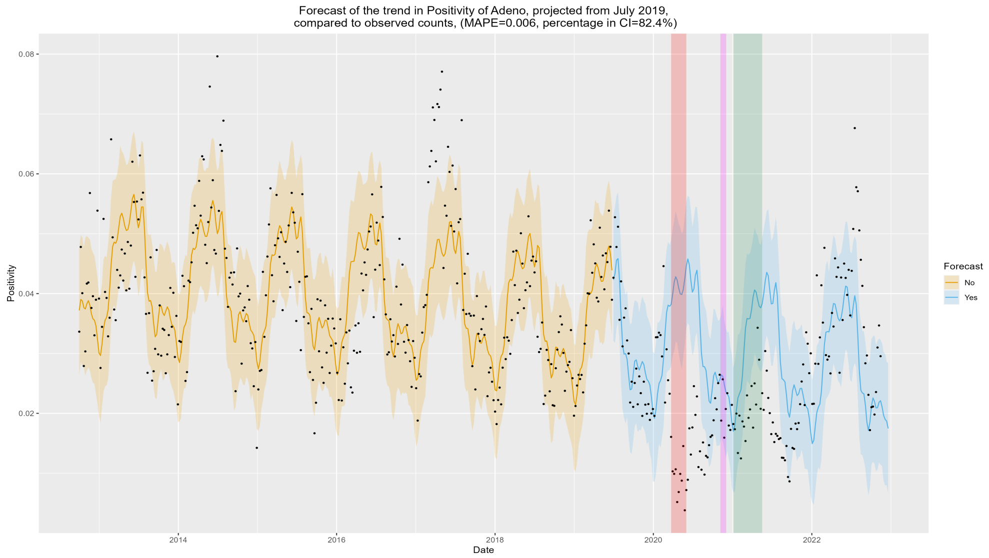
Results

- Our findings suggest that susceptibility affects the timing and the height of a potential influenza wave, with higher susceptibility leading to an earlier and larger influenza wave while vaccine effectiveness controls the size of the peak of the influenza wave.
- With pre-season susceptibility higher than pre-COVID-19 levels, under the planned vaccine programme an early influenza epidemic wave is possible, its size dependent on vaccine effectiveness against the circulating strain.
- If pre-season susceptibility is low and similar to pre-COVID levels, the planned influenza vaccine programme with an effective vaccine could largely suppress a winter 2022 influenza outbreak in England.

Stream A key question

- Is the interplay different across different influenza viruses?





Example of Stream B previous work

Statistical analysis of COG data to quantify the progressive transmissibility of different SARS-CoV-2 variants

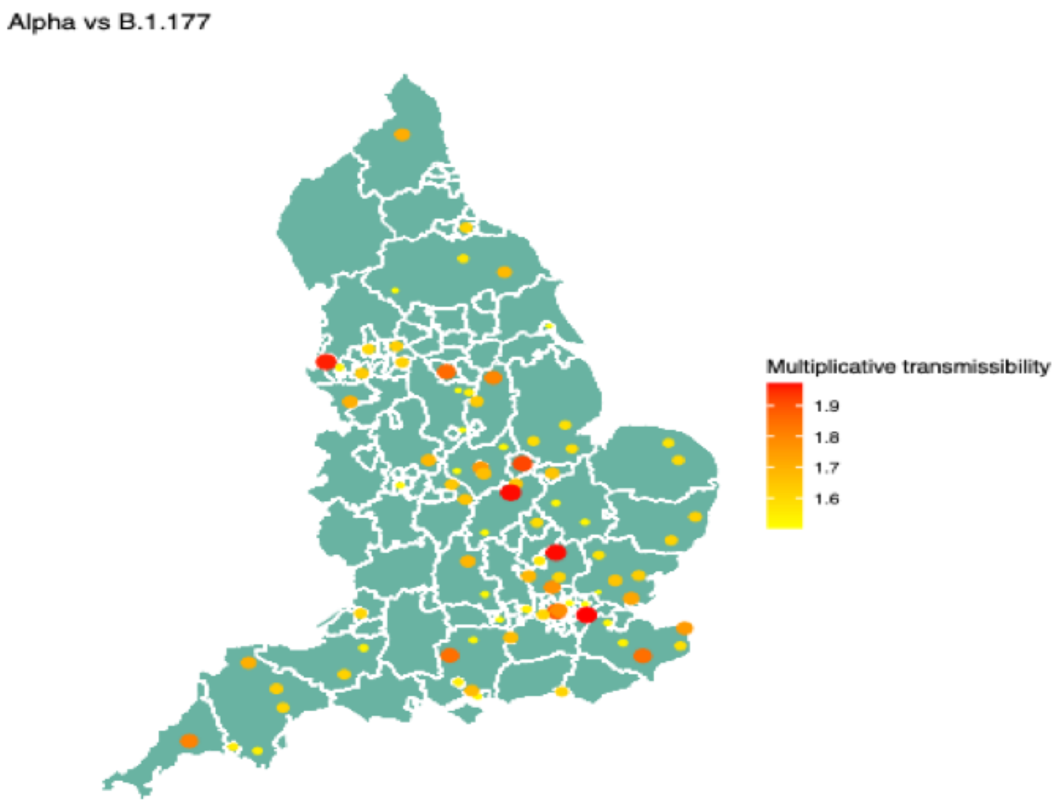
Panovska-Griffiths et al. Phil Trans Roy Soc A (2022)
https://doi.org/10.1098/rsta.2021.0315.

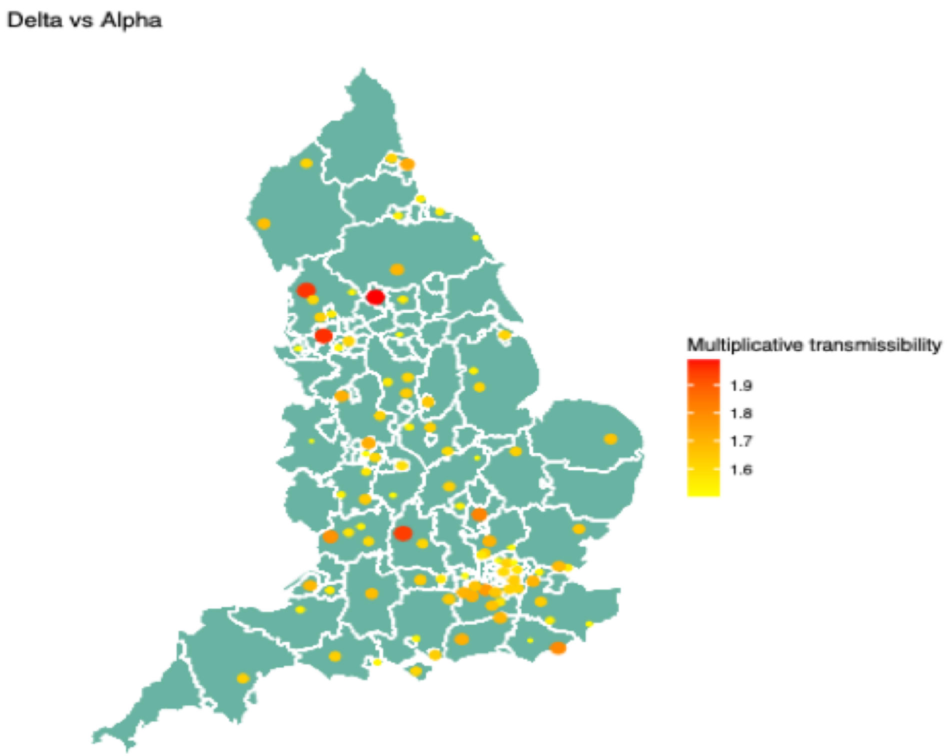
Spatial analysis of transmissibility of emerging COVID-19 variants

- We used publicly available sequencing data from the COG-UK Consortium between September 2020 and June, 2022.
- Multivariate regression analyses quantified the change in growth rate in Alpha vs B.1.177 and Delta vs Alpha (in published paper) and Omicron variants BA.1 and BA.2 relative to the Delta variant AY.4 and between each other (current work).
- The count of each variant in each of the 311 lower tier local authorities (LTLAs) was modelled as a function of multivariate smooth functions across latitude, longitude and day. The latitude and longitude of each district was taken from ONS data and spatial correlation was accounted for using the smooth effects.
- The spatial variation in spread across variants was tested using a hierarchical generalised additive models (HGAM) with negative binomial response distributions as in Pederson et al *PeerJ* 7:e6876

- This is part of a on-going collaboration with Ben Swallow at St.Andrew's University.

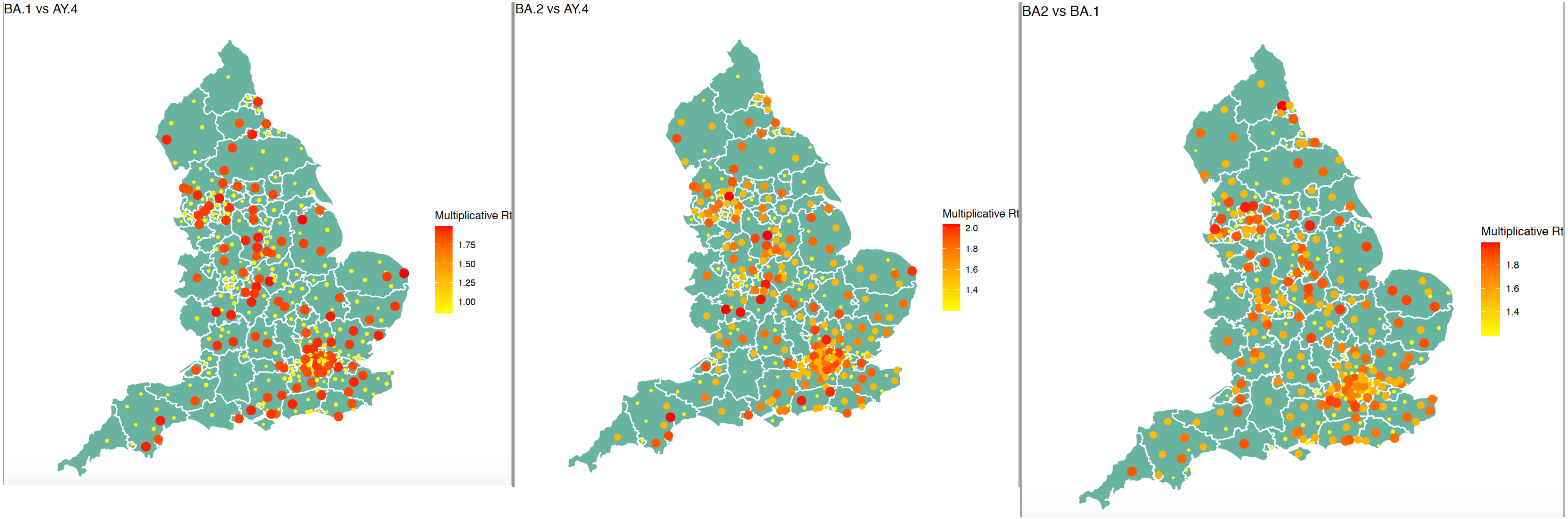
Emerging variants have been progressively more transmissible





Alpha has been more transmissible than B.1.177 and Delta more transmissible than Alpha

Emerging variants have been progressively more transmissible



BA.1 and BA.2 have been notably more transmissible than AY.4 and BA.2 has also been significantly more transmissible than BA.1

Stream B key question

- What is the spillover effect from COVID-19 on other respiratory diseases eg is there well defined seasonality across viruses?