# Outbreak diversity in epidemic waves propagating through distinct geographical scales

Guilherme S. Costa, Wesley Cota and Silvio C. Ferreira

The rapid spreading of COVID-19 mobilized academics from different areas to develop models to understand and predict the behavior of this pathogen. Among the possible approaches, data-driven models, in which a mathematical model is fueled with real data, have proved to be a viable framework to study the epidemic spread of Sars-Cov-2 [1,2]. A central feature of those emerging infectious disease in a pandemic scenario is the spread through geographical scales and the impacts on different locations according to the adopted mitigation protocols. Thus, we investigated a stochastic epidemic model with the metapopulation approach in which patches represent municipalities. Contagion follows a stochastic compartmental model for municipalities; the latter, in turn, interact with each other through recurrent mobility. As a case of study, we consider the epidemic of COVID-19 in Brazil performing data-driven simulations. Properties of the simulated epidemic curves have very broad distributions across different geographical locations and scales, from states, passing through intermediate and immediate regions down to municipality levels. Correlations between delay of the epidemic outbreak and distance from the respective capital cities were predicted to be strong in several states and weak in others, signaling influences of multiple epidemic foci propagating toward the inland cities. The spatio temporal spreading of the pathogen on Brazilian municipalities can be seen in Figure 1 for a weak mitigation scenario. Responses of different regions to the same protocol can vary enormously, implying that the policies of combating the epidemics must be engineered according to the region's specificity but integrated with the overall situation. Real series of reported cases confirm the qualitative scenarios predicted in simulations. Even though we restricted our study to Brazil, the prospects and model can be extended to other geographical organizations with heterogeneous demographic distributions. We acknowledge the funding agencies FAPEMIG, CNPq and CAPES - Finance Code 001

**Keywords:** Epidemic spreading. Metapopulation. Mobility Network. Data-driven modeling

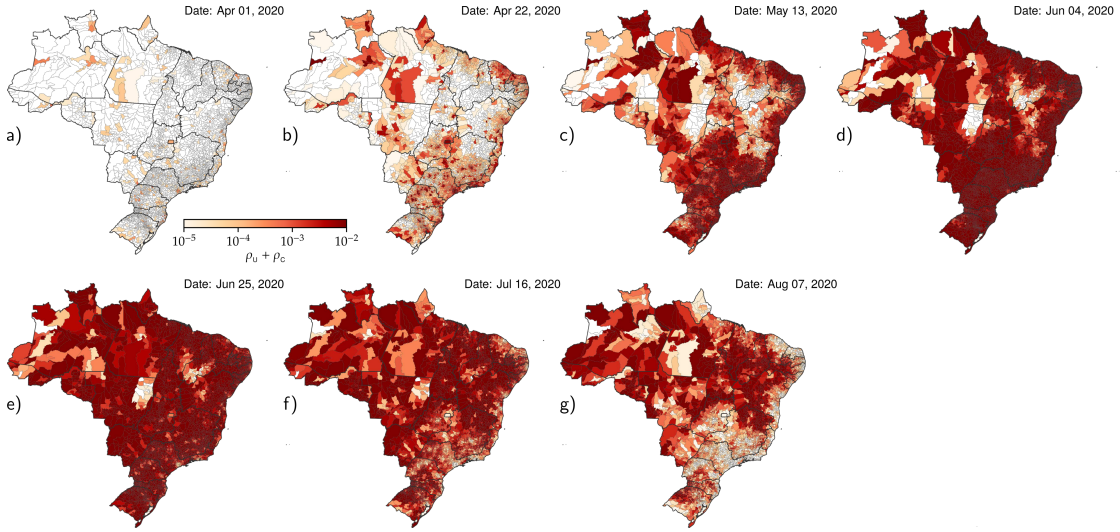


Figure 1: a-g) Color maps presenting the evolution of the prevalence of symptomatic cases for Brazil in a weak mitigation scenario. Dates of the simulations are shown in the upper right corner of each frame. The darker colors represent higher prevalences in a logarithm scale.

## References


1. L. Danon, E. Brooks-Pollock, M. Bailey, and M. Keeling, "A spatial model of covid-19 transmission in england and wales: early spread, peak timing and the impact of seasonality," Philosophical Transactions of the Royal Society B: Biological Sciences, vol. 376, no. 1829, p. 20200272, 2021.

2. A. Arenas, W. Cota, J. Gómez-Gardeñes, S. Gómez, C. Granell, J. T. Matamalas, D. Soriano-Paños, and B. Steinegger, "Modeling the spatiotemporal epidemic spreading of covid-19 and the impact of mobility and social distancing interventions," Phys. Rev. X, vol. 10, p. 041055, Dec 2020.