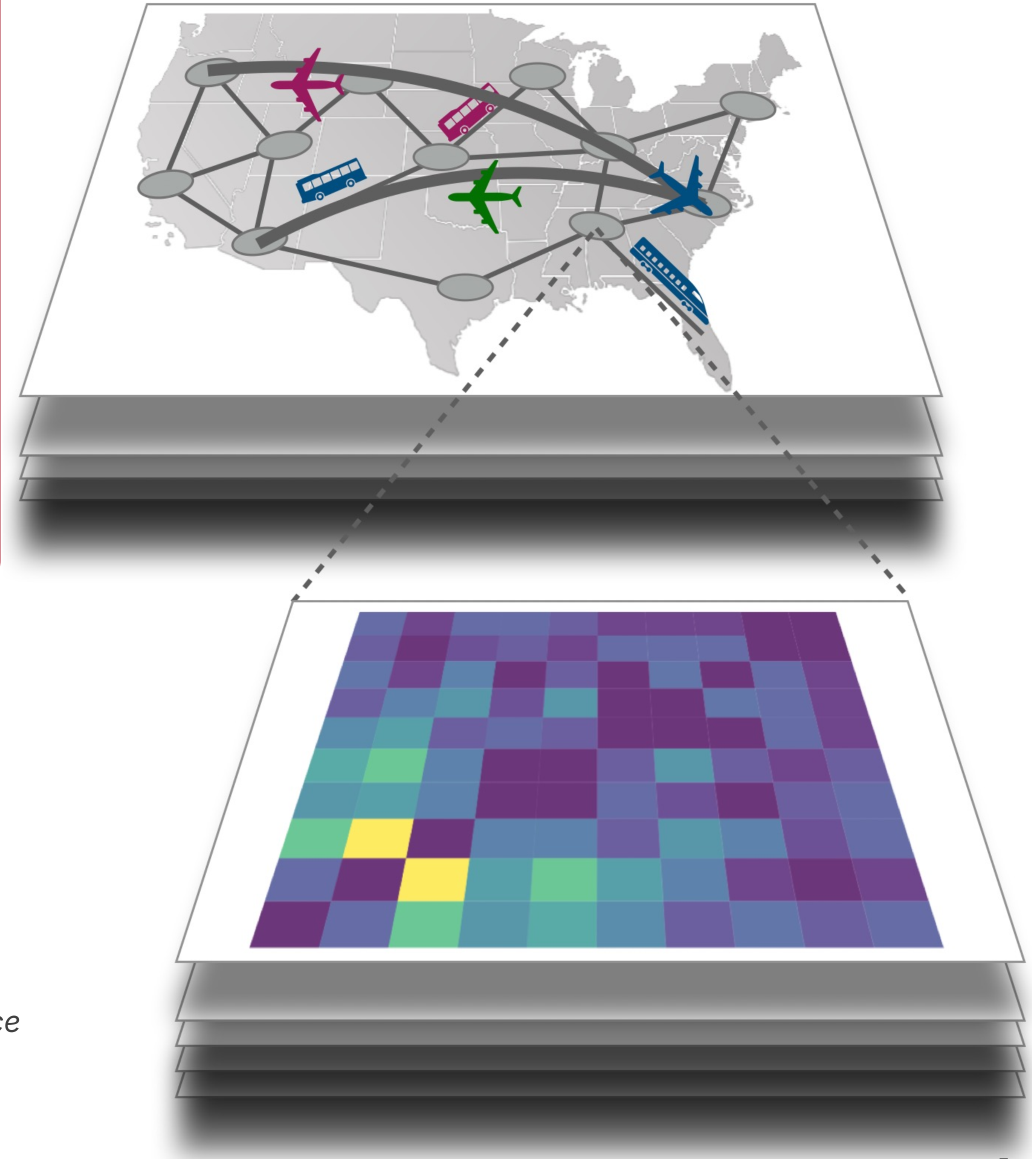
Critical behavior of epidemics depending on the interplay between temporal scales and human behavior



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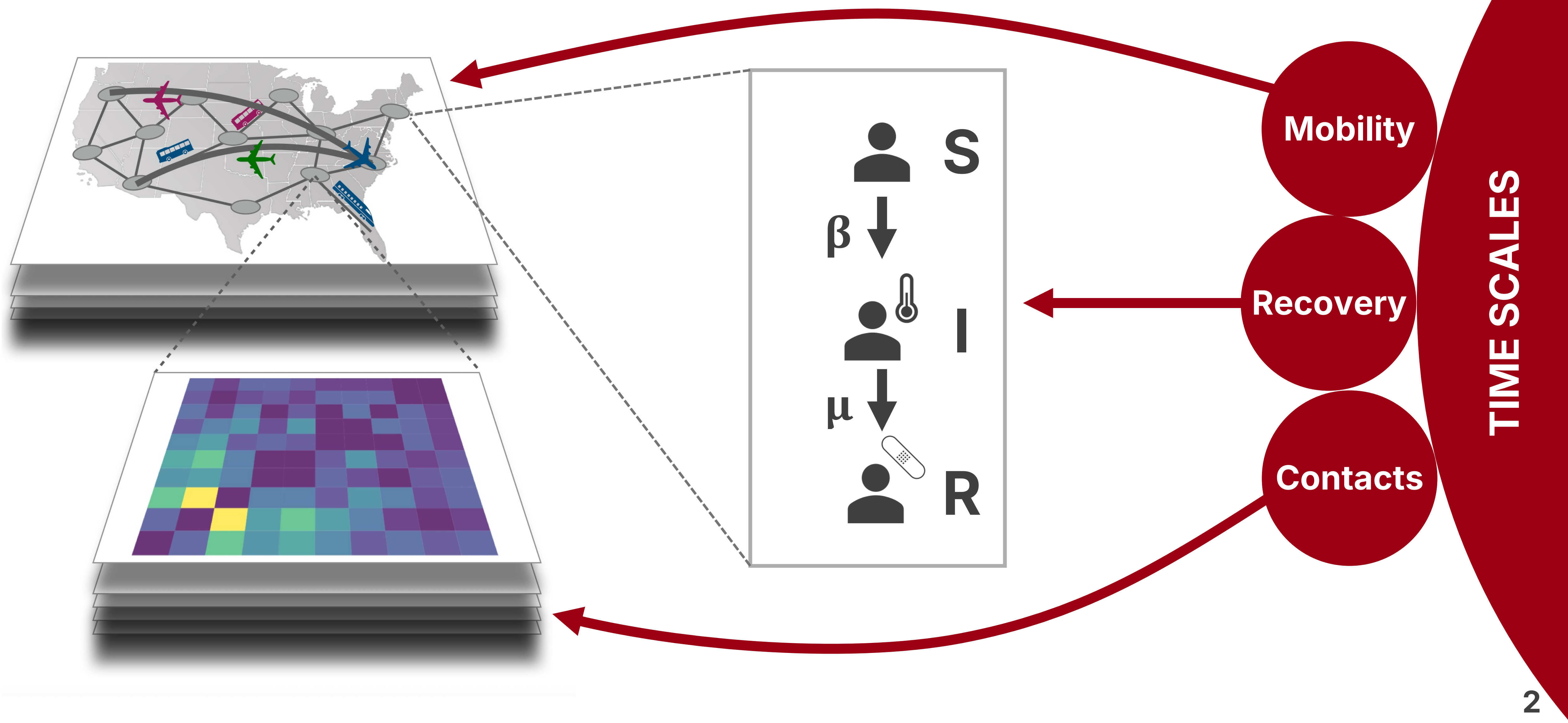
Starting point: the epidemic model

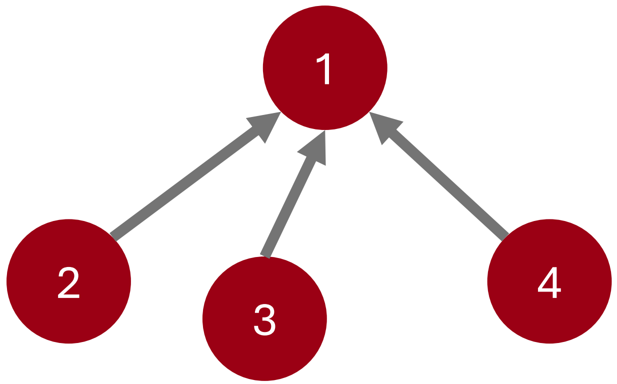


Can we describe the system and **preserve the population** in each patch?

Do **mobility** and **constacts affect the outcome of the epidemic**?

Does **varying the time scales** change the critical regimes?

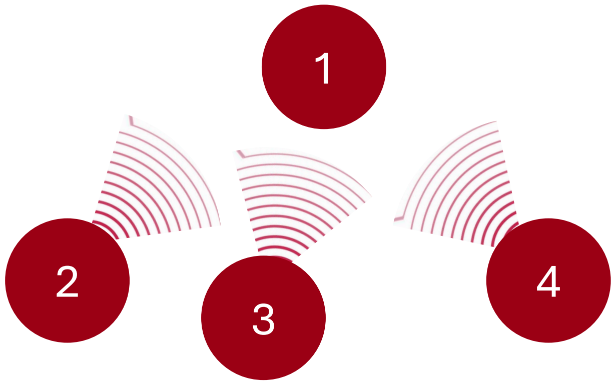
Particle based "Reaction Diffusion"



Individuals **move** between spatial patches

$$P_{\text{infected}} = 1 - \left(1 - \left(\frac{\beta\tau}{N_i}\right)\right)^{I_i}$$

Force of Infection for mobility

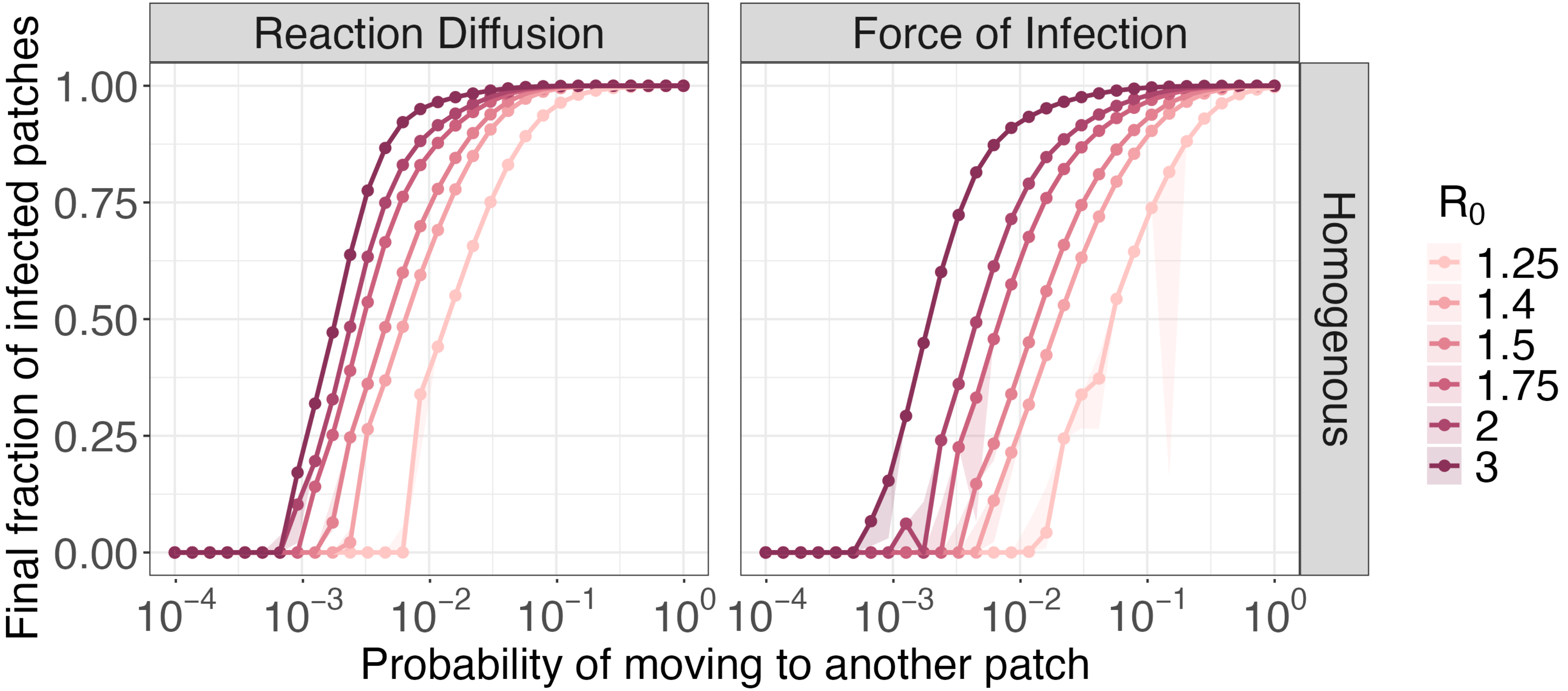


Individuals **'perceive'** infected neighbors

$$\lambda_i = \beta \left[\sum_j^V \frac{P_{ji} N_j}{\sum_k P_{ki} N_k} \frac{I_j}{N_j} \right]$$

$$P_{\text{infected}} = 1 - \exp\left(-\lambda_i \tau\right)$$

Varying mobility: affecting system response



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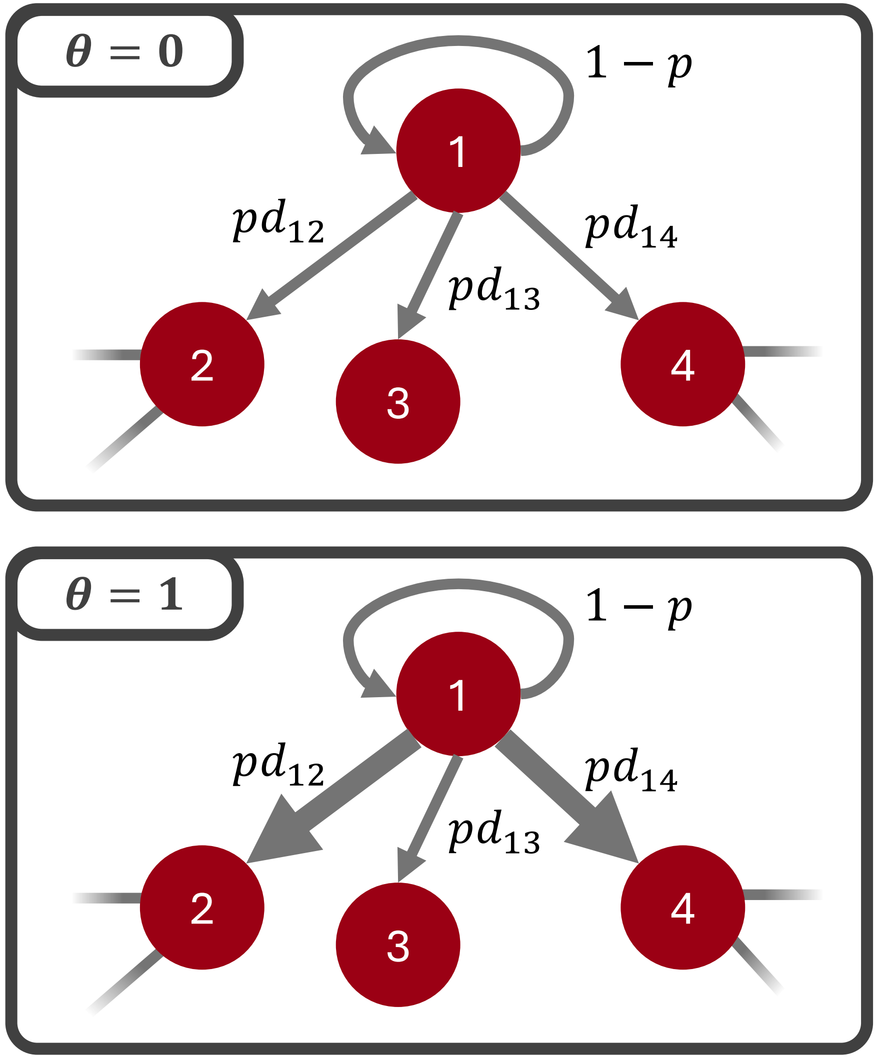
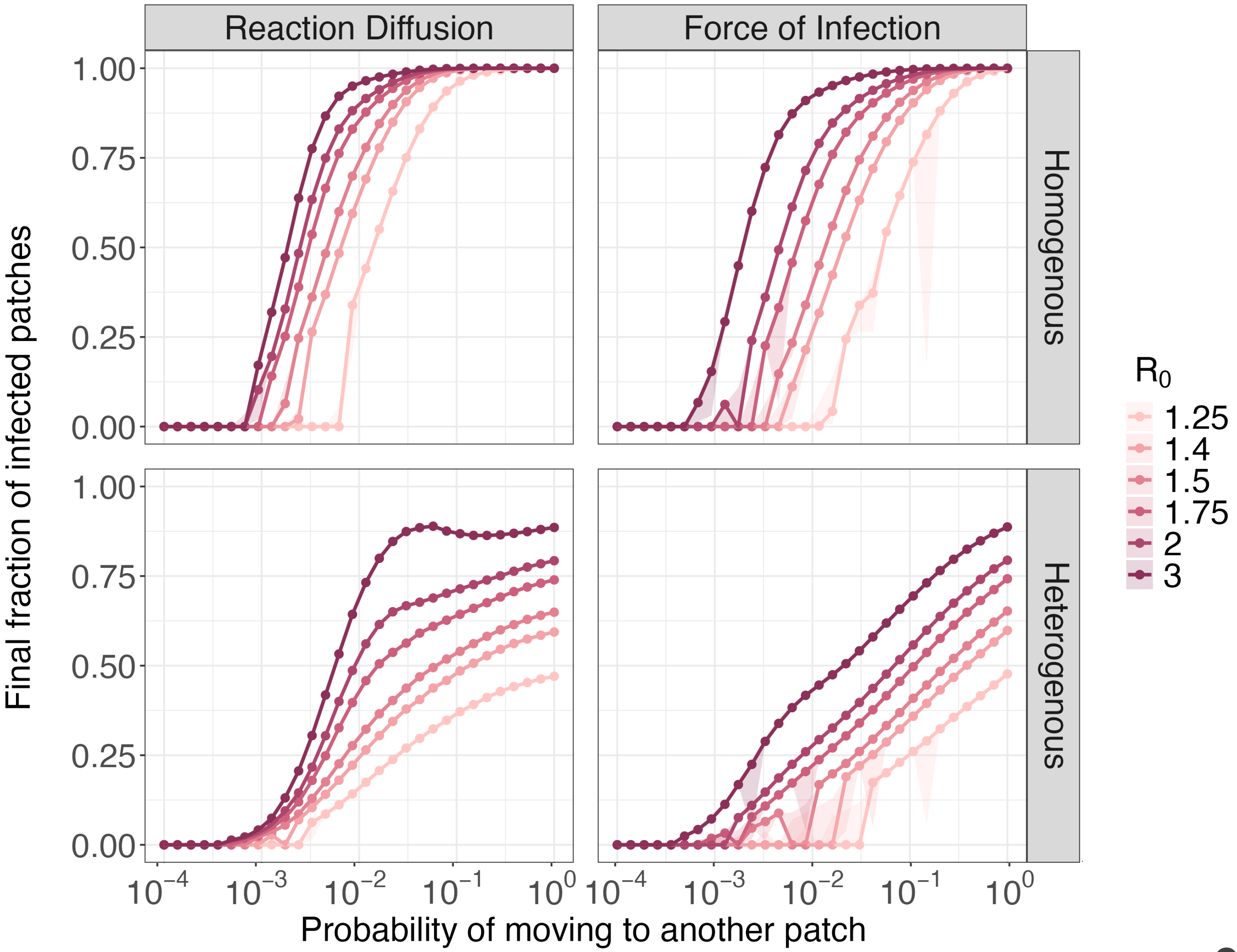




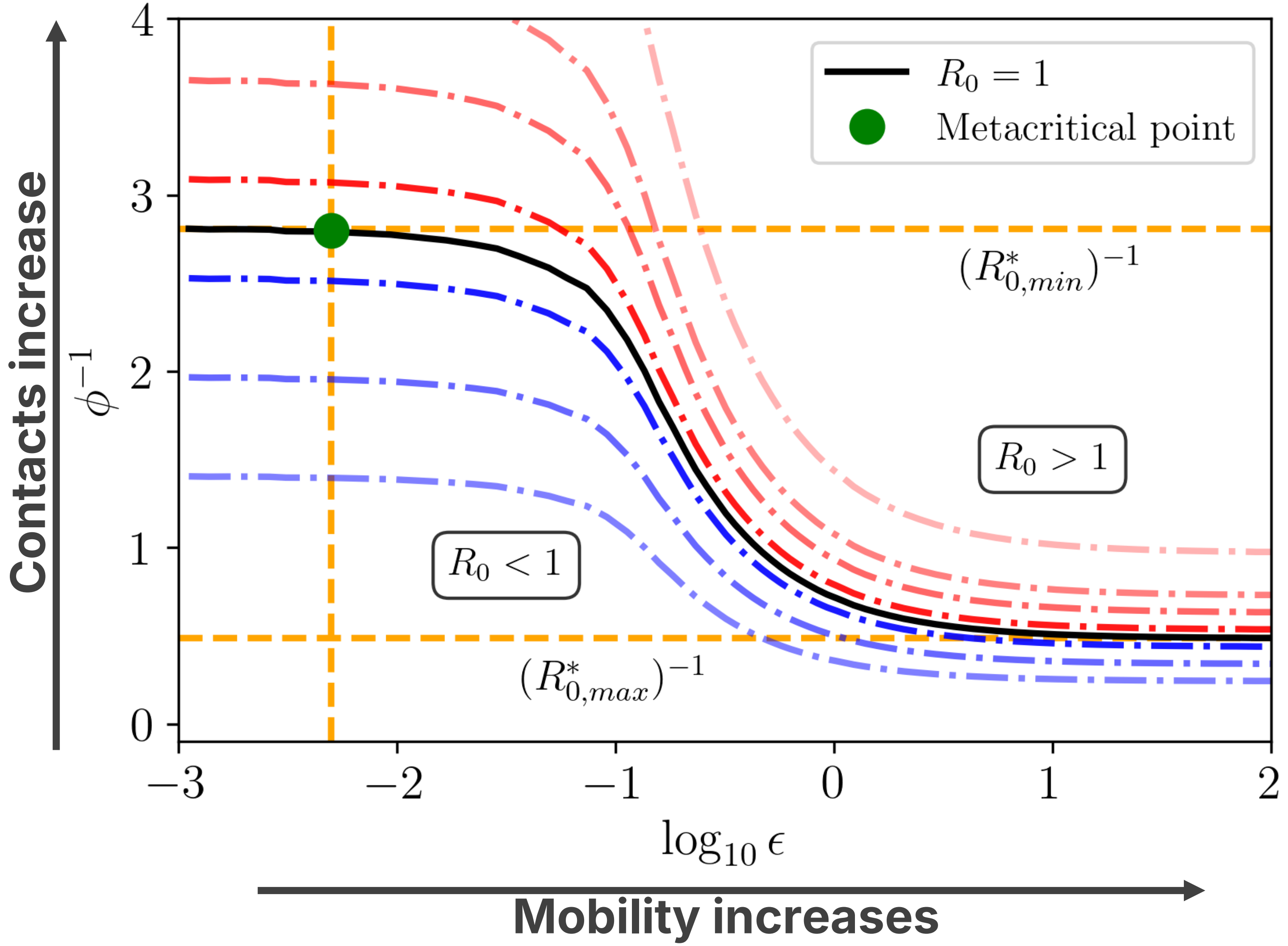
$$d_{ij} \propto (k_i k_j)^{\theta} \quad i \neq j$$

Varying mobility: the metacritical point

$$\frac{dI_{ia}}{dt} = -\mu_{ia} I_{ia}$$

Contact $+\boxed{\frac{1}{\phi}}\left[S_{ia}\sum_{a'}\lambda_{i,aa'}\frac{I_{ia'}}{N_{ia'}}\right]$

Mobility $-\boxed{\frac{1}{\epsilon}}\left[\sum_{j}P_{ij}I_{ia} - \sum_{j}P_{ji}I_{ja}\right]$



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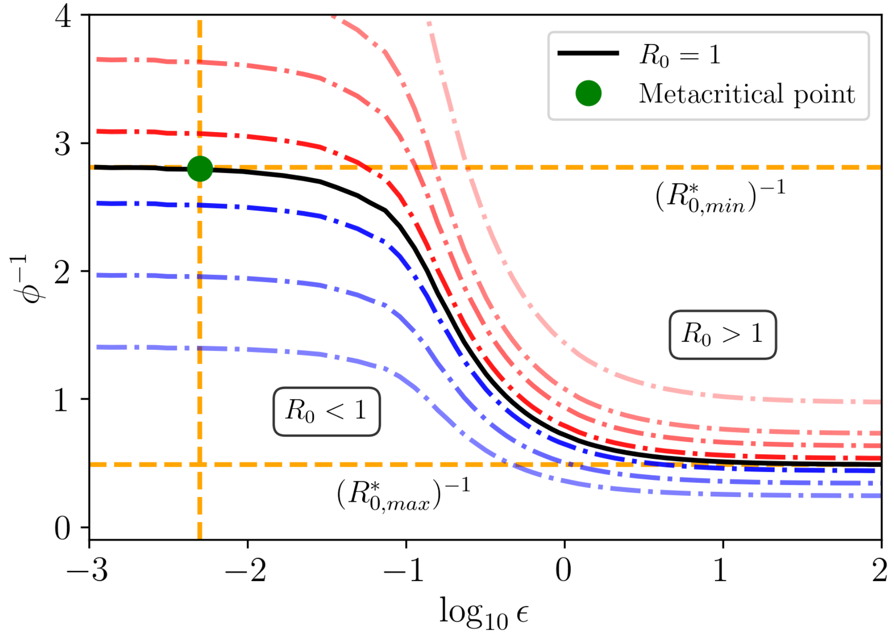
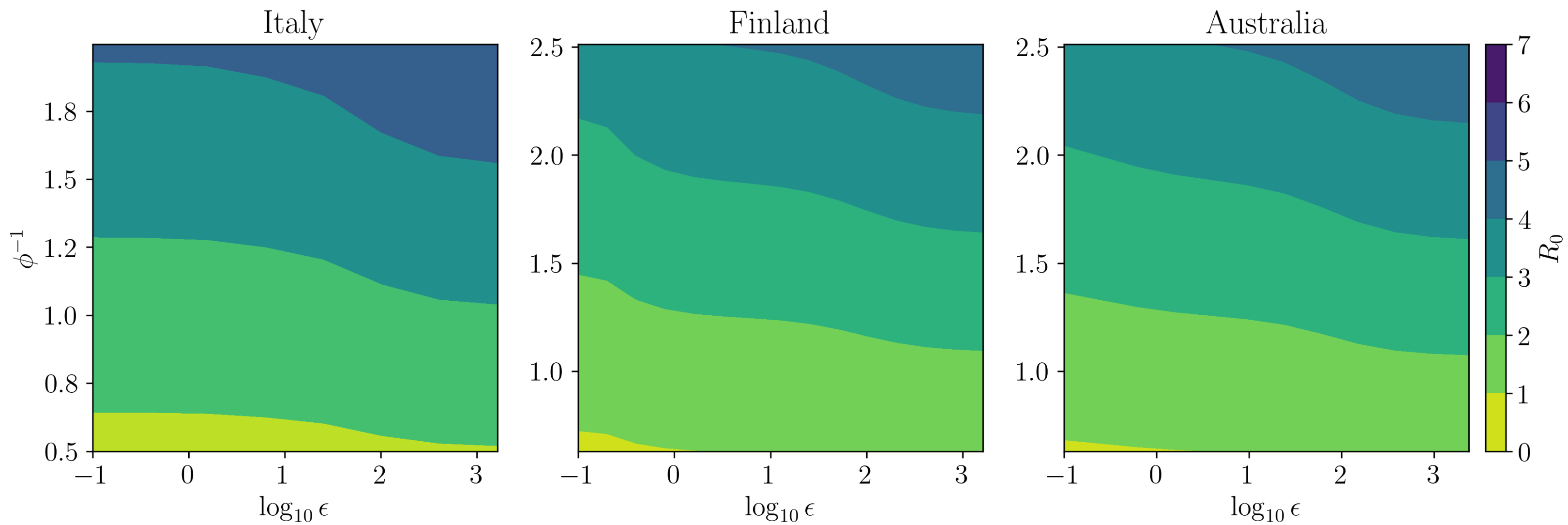


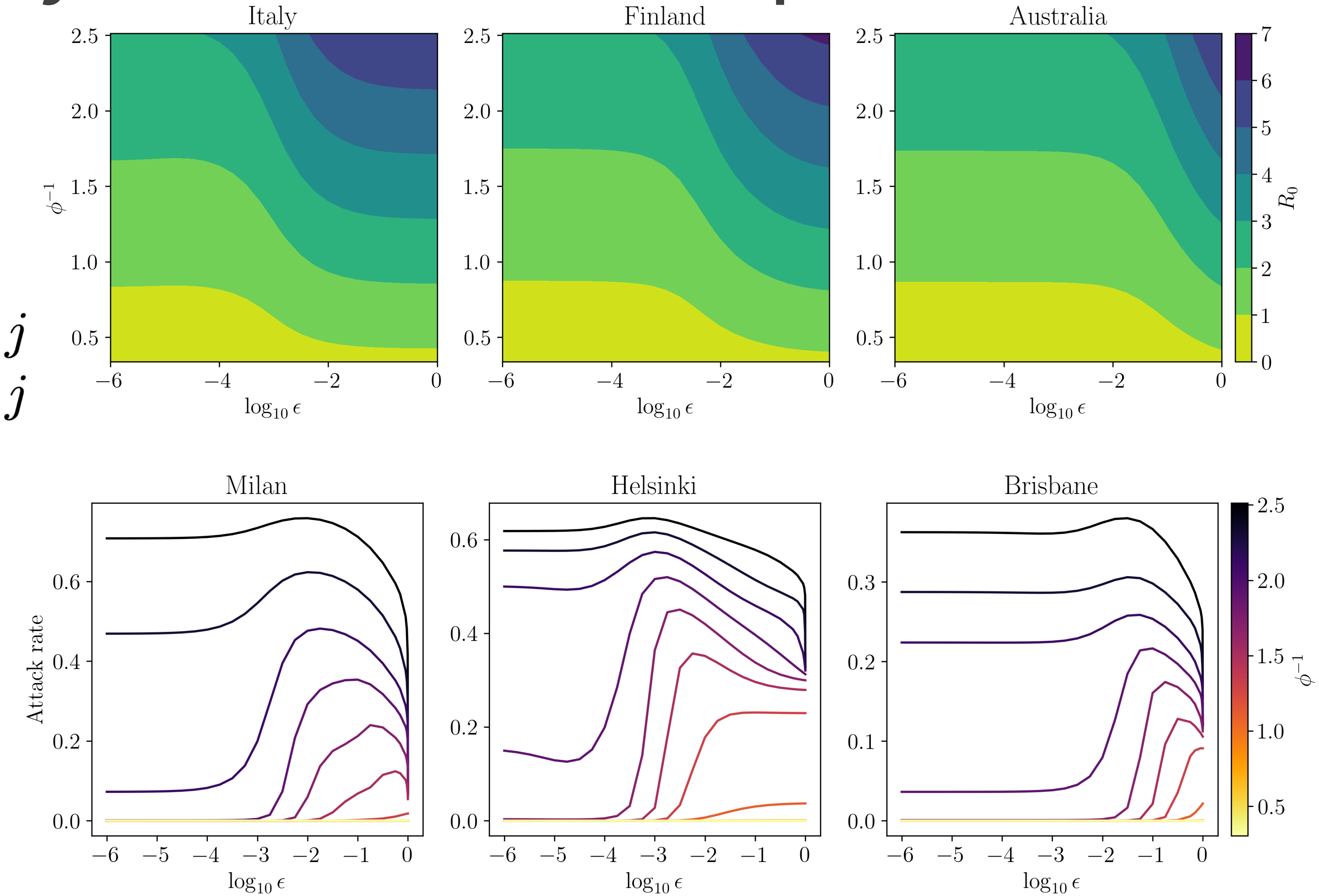


Mistry, D. *et al. Nat Commun* **12**, 323 (2021).

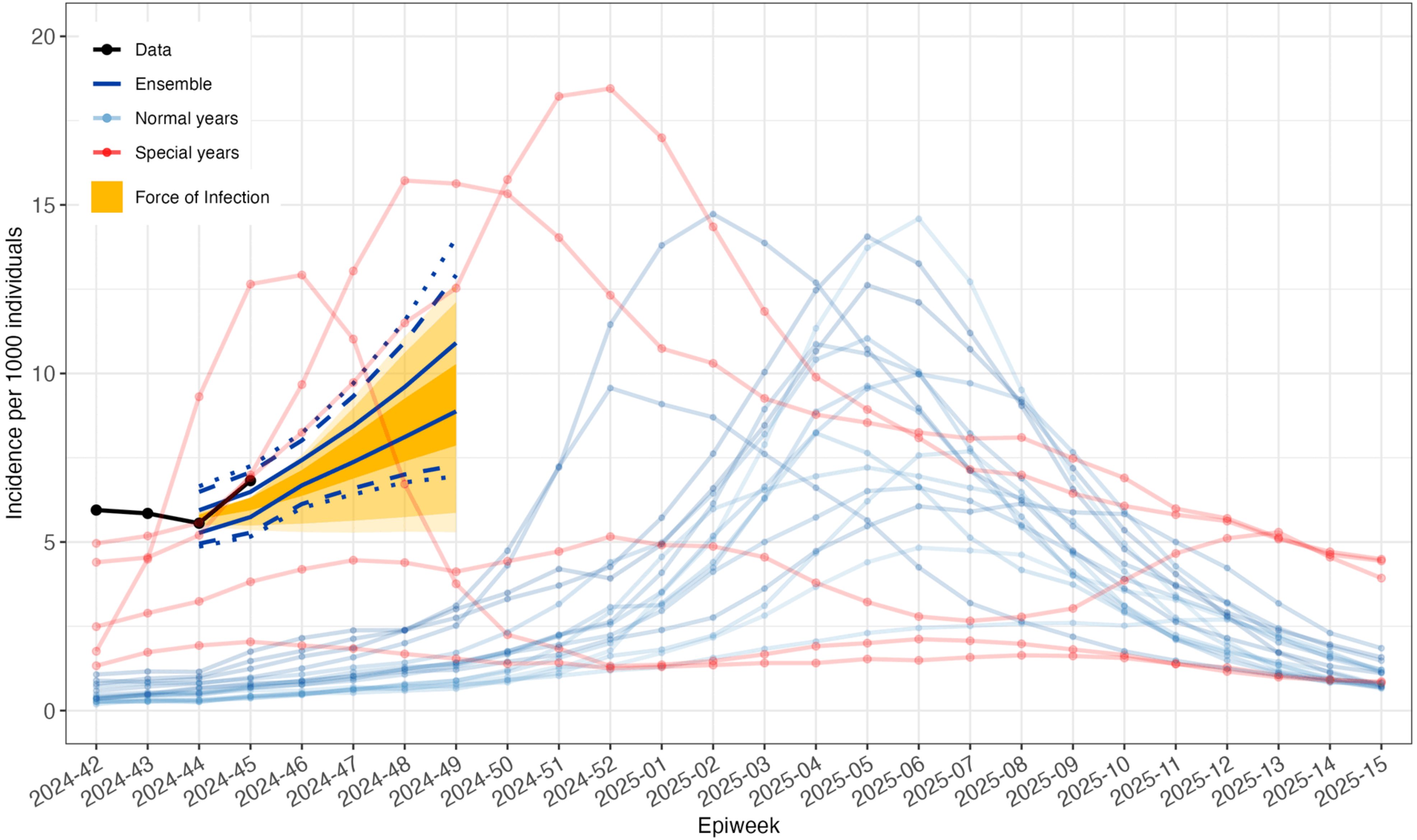
Varying mobility: the metacritical point

$$P_{ij}^{(\epsilon)} = \begin{cases} (1-\epsilon)P_{ij} & \text{if } i \neq j \\ \epsilon P_{ij} & \text{if } i = j \end{cases}$$

$$\lambda_{aa'}^{(\phi)} = \frac{1}{\phi}\lambda_{aa'}$$



Seasonal influenza forecasting in Italy



Summing up and final considerations

We introduce a force of infection formulation for mobility

It yields qualitatively comparable results, consistent with other methods

It preserves the number of individuals in each spatial patch

We vary the timescales of contacts and mobility

A metacritical point emerges, clearly separating different regimes

New models could focus on other timescales: vaccination rates, pathogen mutation rates, NPI adoption, ...

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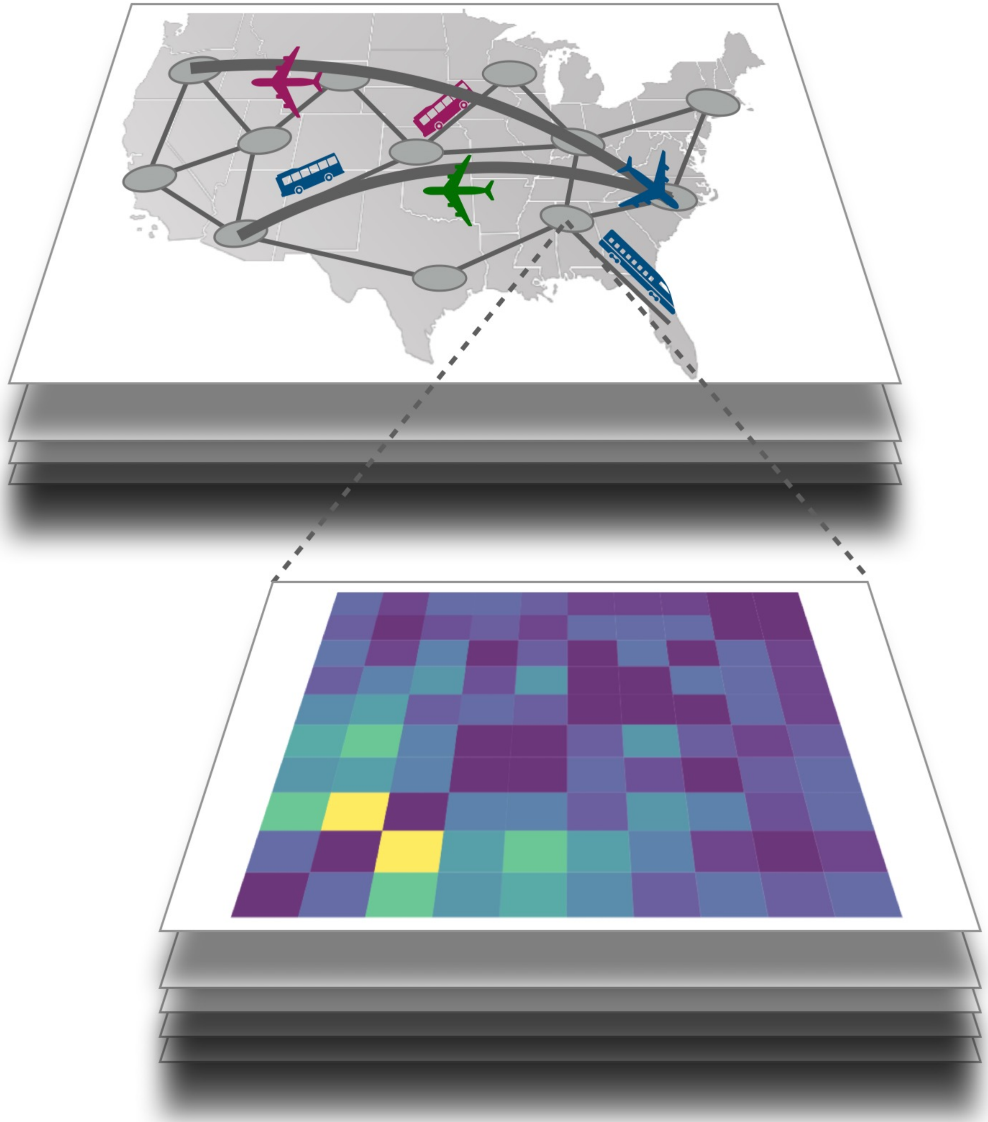

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