ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

P2.6.10

Modeling the spread of cholera using human mobility estimates derived from mobile phone records

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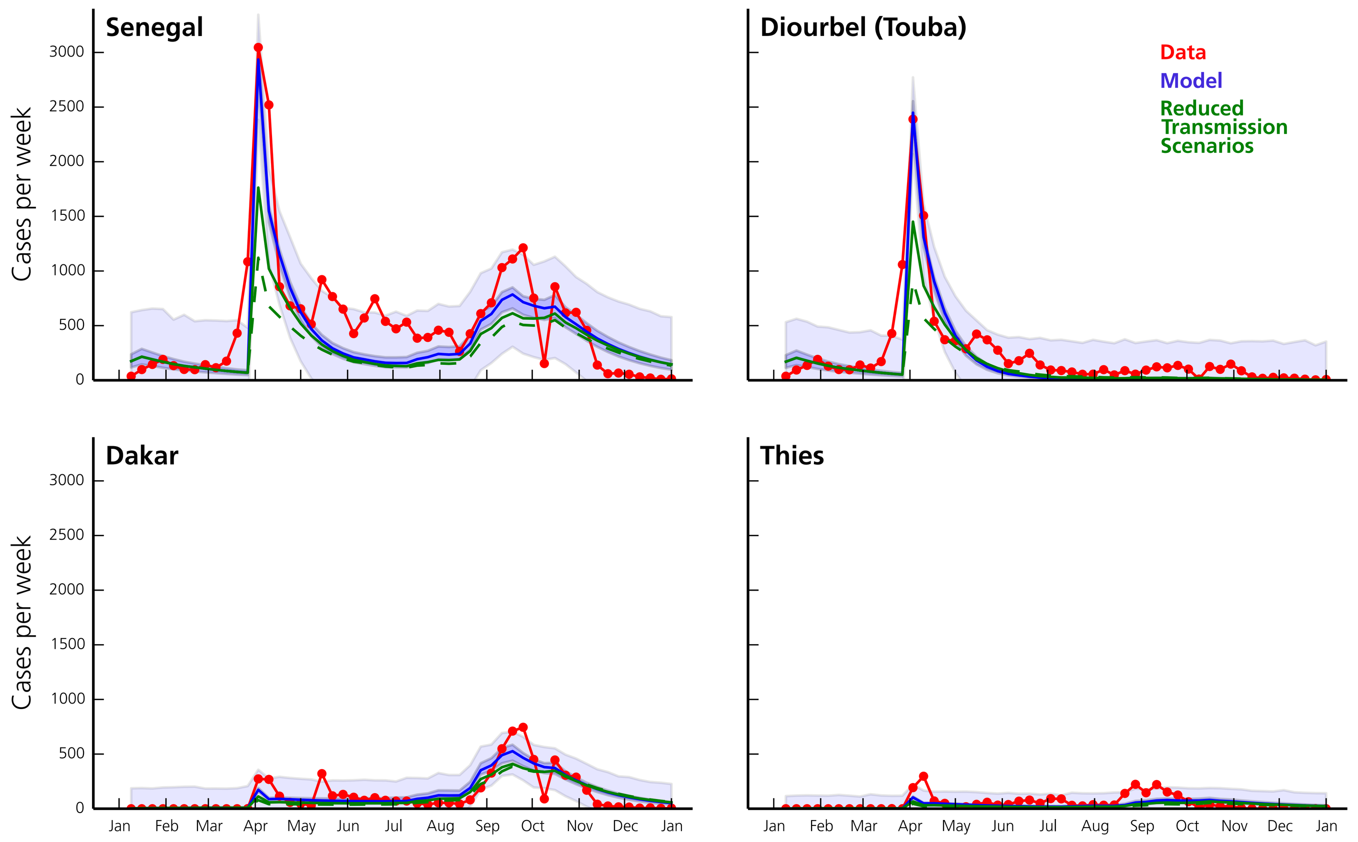
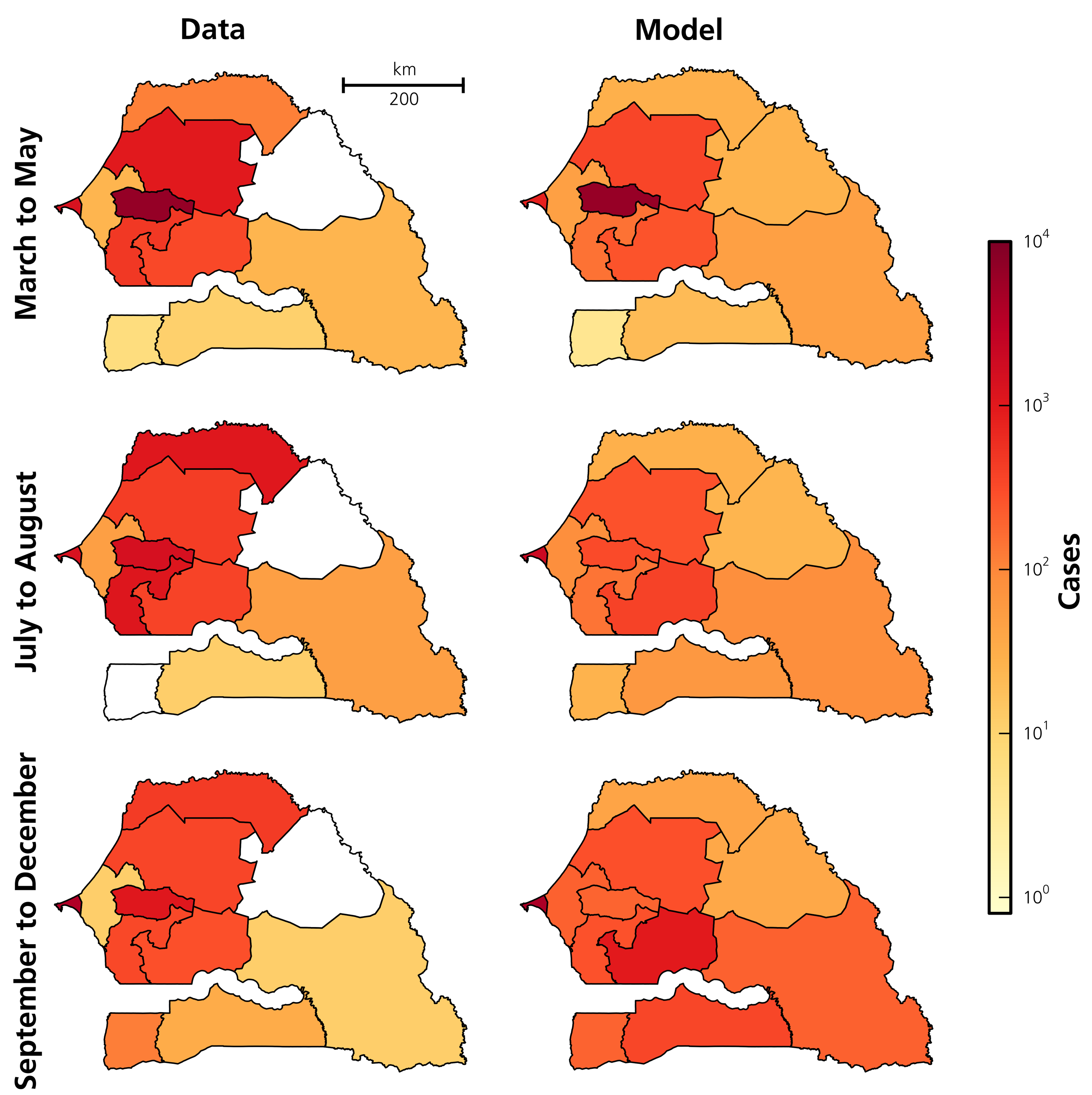
2005 cholera epidemic in Senegal



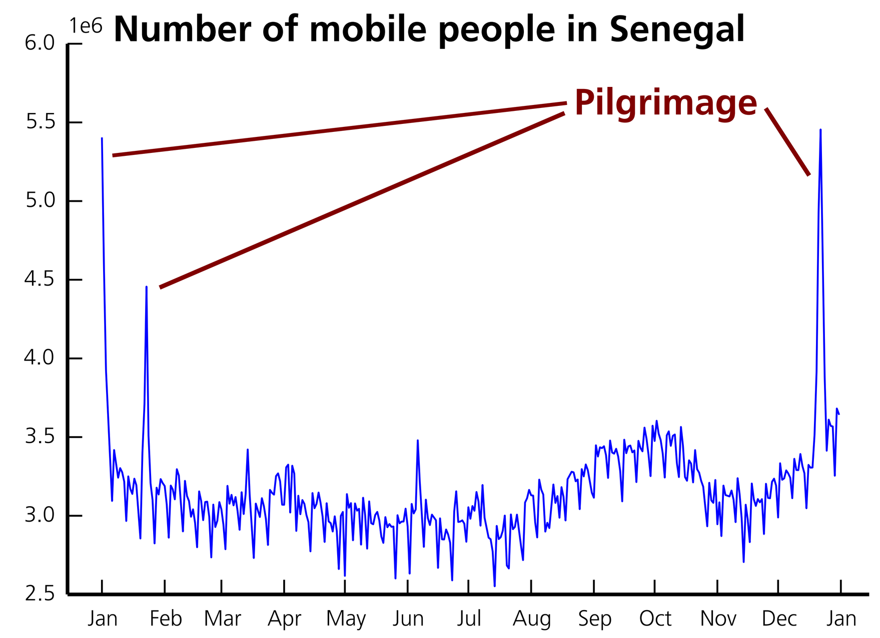
- Peak end of March related to **pilgrimage in Touba**
- Flare and spread due to **overcrowding and travelling pilgrims**
- Peak in Dakar in autumn related to **rainfall and floods**
- **Scenarios of reduced transmission** during pilgrimage

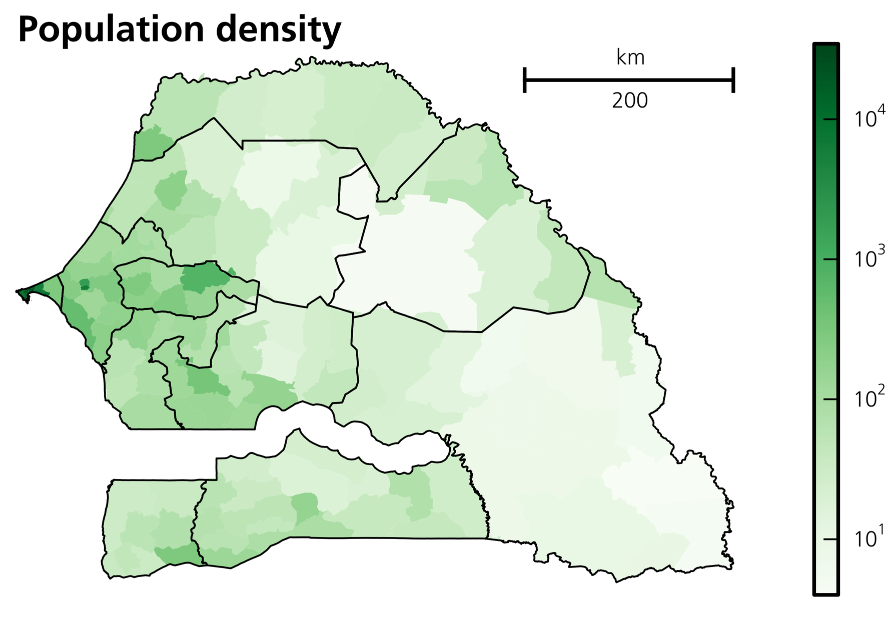


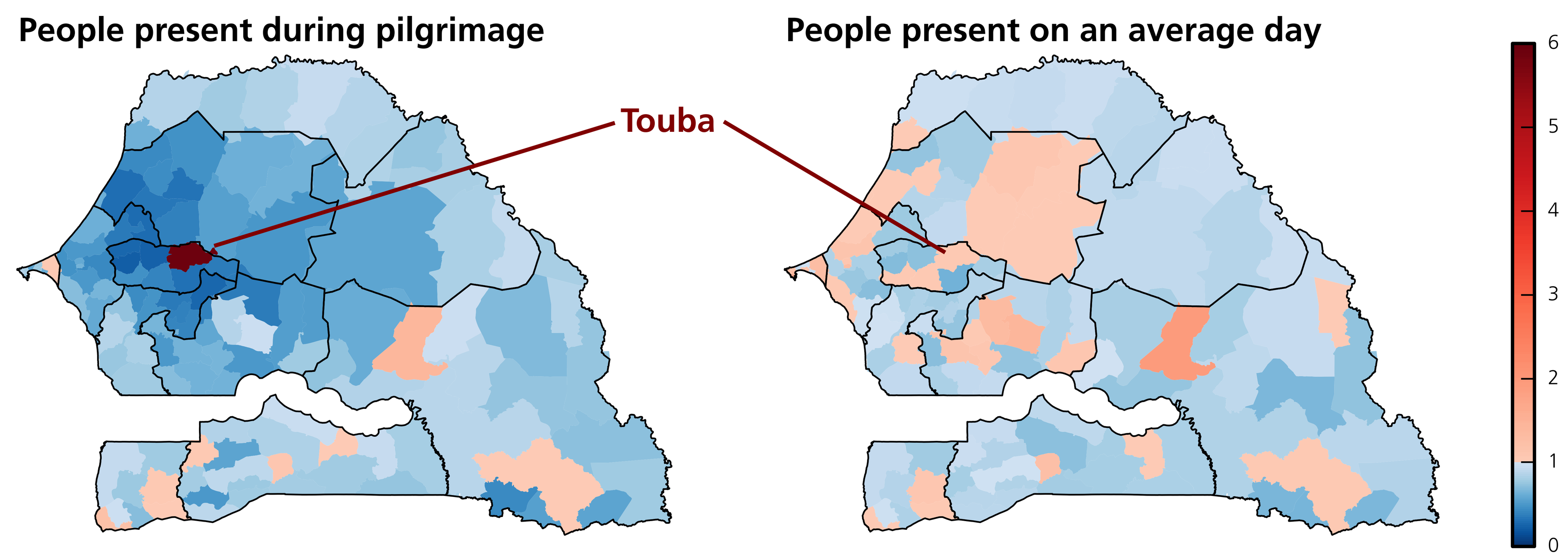
Overview

- We analzye a dataset of **mobile phone call** records in Senegal and **extract human mobility fluxes** over a period of one year.
- The fluxes are directly used in a **spatially explicit, mechanistic epidemiological model** of the **2005 cholera epidemic in Senegal**.
- The spread of the epidemic was boosted by a **mass gathering of 3 million pilgrims**.
- This **crucial effect** could only be accounted for thanks to the first-order information about **origin, destination and number of travellers per day** not present in other data sources.

Mobile phone data analysis

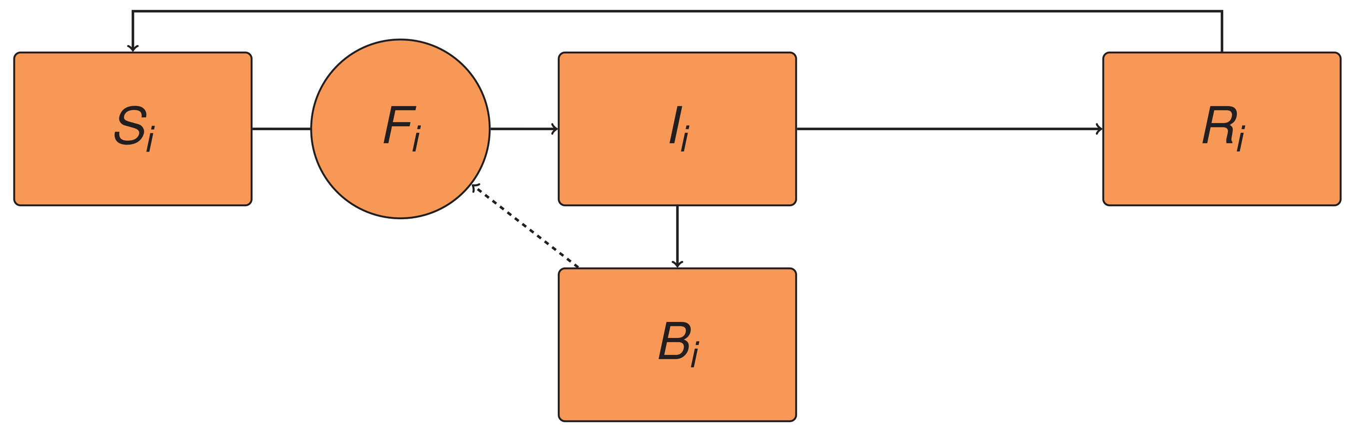






- 150,000 mobile phone users over the year 2013.
- Determination of **home district** of each user using **calls made at night**
- **Time spent** at node j by users with home node i proportional to **number of calls** they made at j.
- $\mathbf{Q_{ij}(t)}$ contains the **average fraction of time** spent by users of note i at node j during day t.

Cholera model



$$\frac{dS_i}{dt} = \mu(H_i - S_i) - \mathcal{O}_i(t)\mathcal{F}_i(t)S_i + \rho R_i$$
$$\frac{dI_i}{dt} = \sigma\mathcal{O}_i(t)\mathcal{F}_i(t)S_i - (\gamma + \mu + \alpha) I_i$$
$$\frac{dR_i}{dt} = \gamma I_i + (1-\sigma)\beta_i(t)\mathcal{O}_i(t)\mathcal{F}_i(t)S_i - (\rho + \mu) R_i$$
$$\frac{dB_i}{dt} = -\mu_B B_i + \frac{\theta}{H_i}[1 + \lambda J_i(t)]\,\mathcal{O}_i(t)\mathcal{G}_i(t)$$

- Spatially explicit SIRB type model
- Fluxes from mobile phone data employed directly within the model to account for pathogen spread
- Overcrowding effect $\mathcal{O}_i(t)$
- Rainfall
- 6 calibration parameters

$$\mathcal{O}_i(t) = \exp\left(\frac{\omega}{H_i}\sum_{j=1}^{N} Q_{ji}(t)H_j\right)$$
$$\mathcal{F}_i(t) = \beta\sum_{j=1}^{N} Q_{ij}(t)\frac{B_j}{K + B_j}$$
$$\mathcal{G}_i(t) = \sum_{j=1}^{N} Q_{ji}(t)I_j.$$

Targeted interventions