2005 cholera epidemic in Senegal

Overview

► We analyze 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

► 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

Cholera model

\[
\frac{dS_t}{dt} = \mu (H_t - S_t) - Q(t) F_t S_t + \rho R_t \\
\frac{dI_t}{dt} = \sigma Q(t) F_t S_t - (\gamma + \mu + \alpha) I_t \\
\frac{dR_t}{dt} = \gamma I_t + (1 - \sigma) \beta(t) O(t) F_t (I_t - (\mu + \rho) R_t) \\
\frac{dR_t}{dt} = -\mu R_t + \frac{\theta}{F_t} [1 + \lambda(t)] O(t) G(t)
\]

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

\[
O(t) = \exp \left( \frac{\omega}{H_t} \sum_{j=1}^{N} Q_j(t)H_j \right) \\
F(t) = \beta \sum_{j=1}^{N} \frac{Q_j(t)B_j}{R_t + B_j} \\
G(t) = \sum_{j=1}^{N} Q_j(t)I_j
\]

Targeted interventions

► 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 \( j \).
► \( Q_i(t) \) contains the average fraction of time spent by users of note \( i \) at node \( j \) during day \( t \).