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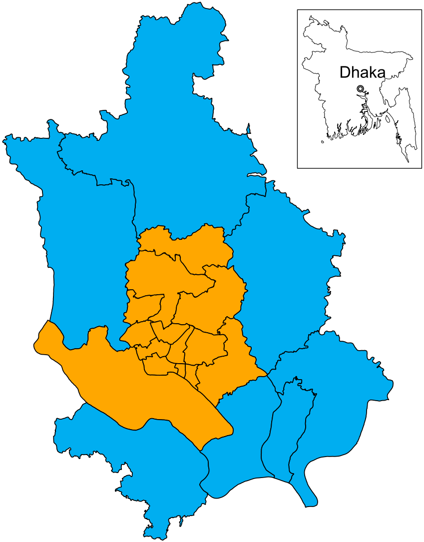
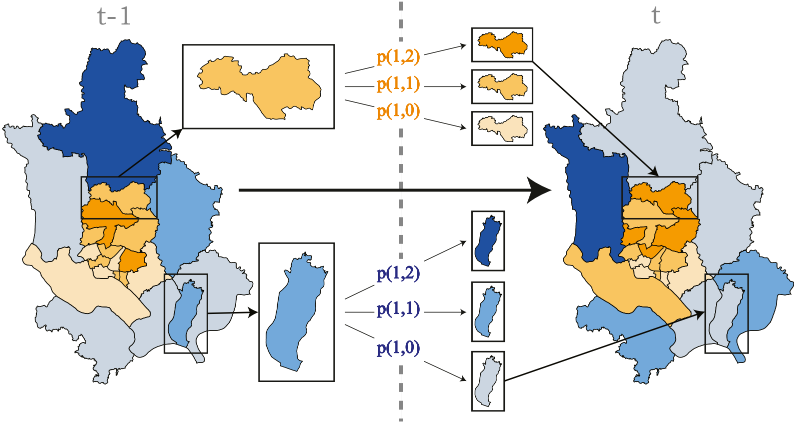
Cholera in Dhaka



Reiner et al., 2012

Multidimensional
Inhomogenous
Markov Chain



Reiner et al., 2012

Basic			Climate
Infection	Neighbors	Season	ENSO

Transition probabilities

$$p_{i,0,k,t} = \mathbb{P}_{i,0,\mathcal{D}(k)} \times \mathrm{Neigh}(i, 0, \mathcal{V}(k, t-1), \mathcal{D}(k)) \\ \times \mathrm{Seas}(i, 0, t-1, \mathcal{D}(k))$$

$$p_{i,2,k,t} = \mathbb{P}_{i,2,\mathcal{D}(k)} \times \mathrm{Neigh}(i, 2, \mathcal{V}(k, t-1), \mathcal{D}(k)) \\ \times \mathrm{Seas}(i, 2, t-1, \mathcal{D}(k))$$

$$p_{i,1,k,t} = 1 - p_{i,0,k,t} - p_{i,2,k,t}$$

Neighbors

$$\mathrm{Neigh}(i, j, v, d) = (1 + \alpha_{i,j,d})^{v}, \quad j = 0, 2$$

Seasonality

$$\mathrm{Seas}(i, j, t, d) = (1 + \beta_{i,j,d})^{\mathrm{Se}(t,d)}, \quad j = 0, 2$$

Modified transition probability

$$p'_{i,2,k,t} = f\left(p_{i,2,k,t} \times \mathrm{Nino}(t-1, \mathcal{D}(k))\right)$$

$$f(x) = \min(1, \max(0, x))$$

El Niño

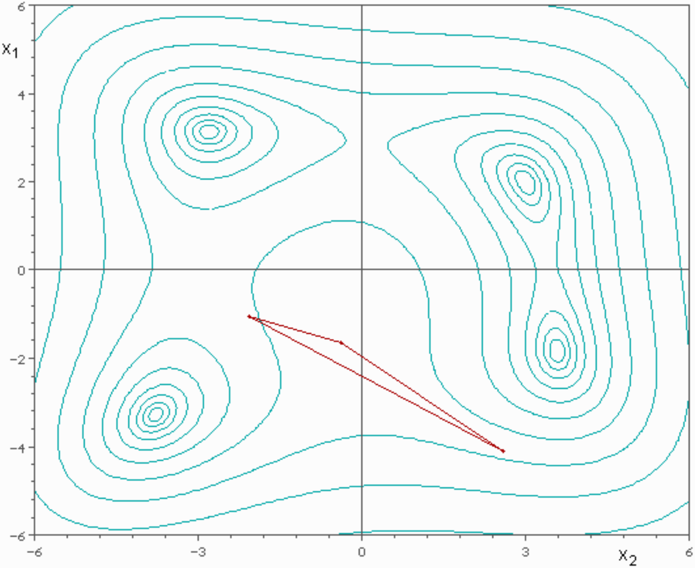
$$\mathrm{Nino}(t, d) = 1 + A_d \frac{\tan\left(\frac{h_d}{2} \cdot \frac{\mathrm{ENSO}(t-10)}{M_d}\right)}{\tan\left(\frac{h_d}{2}\right)}$$

Scaling

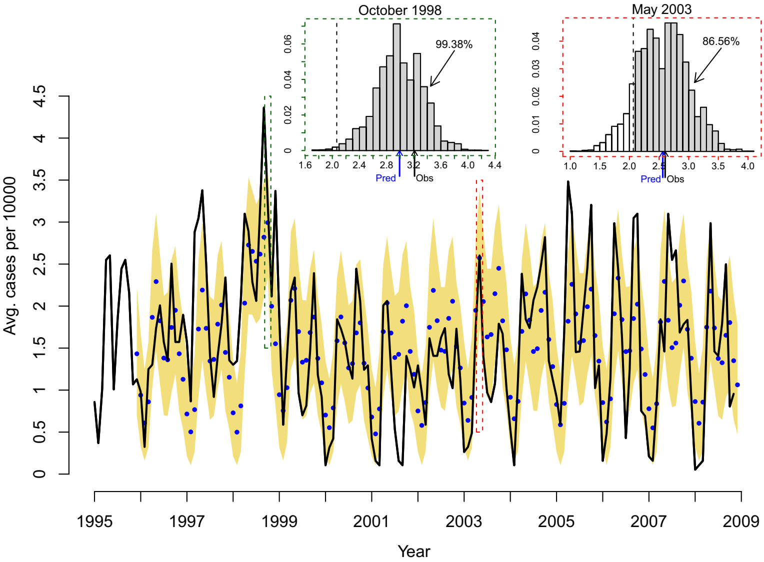
$$p'_{i,0,k,t} = (1 - p'_{i,2,k,t}) \frac{p'_{i,0,k,t}}{p'_{i,0,k,t} + p'_{i,1,k,t}}$$

$$p'_{i,1,k,t} = (1 - p'_{i,2,k,t}) \frac{p'_{i,1,k,t}}{p'_{i,0,k,t} + p'_{i,1,k,t}}$$

Model Fitting?



https://upload.wikimedia.org/wikipedia/commons/9/96/Nelder_Mead2.gif



Reiner at al., 2012

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Spatial SEIR

$$\frac{dS_i}{dt} = \mu - \mu S_i - S_i \sum_{j=1}^{n} \beta_{ij} I_j$$

$$\frac{dE_i}{dt} = S_i \sum_{j-1}^{n} \beta_{ij} I_j - (\mu + \sigma) E_i$$

$$\frac{dI_i}{dt} = \sigma E_i - (\mu + \gamma) I_i$$

$$+$$

$$R_i = 1 - S_i - E_i - I_i$$

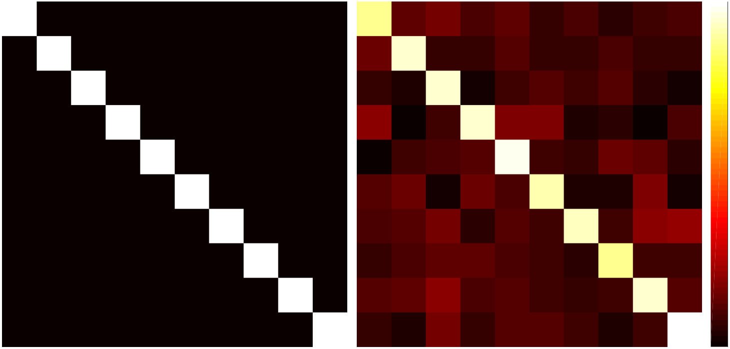
$$\frac{dS_i}{dt} = \mu - \mu S_i - S_i \sum_{j=1}^{n} \beta_{ij} I_j$$

$$\frac{dE_i}{dt} = S_i \sum_{j-1}^{n} \beta_{ij} I_j - (\mu + \sigma) E_i$$

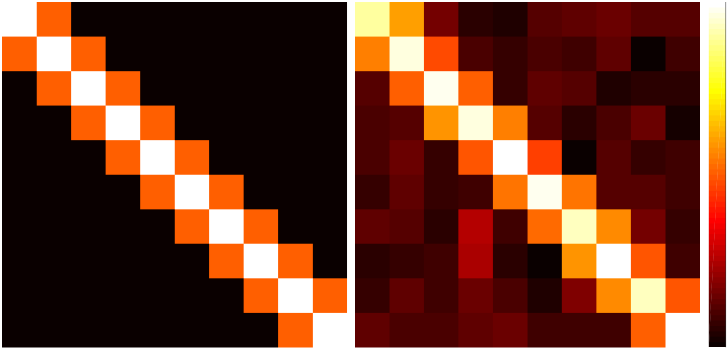
$$\frac{dI_i}{dt} = \sigma E_i - (\mu + \gamma) I_i$$

$$+$$

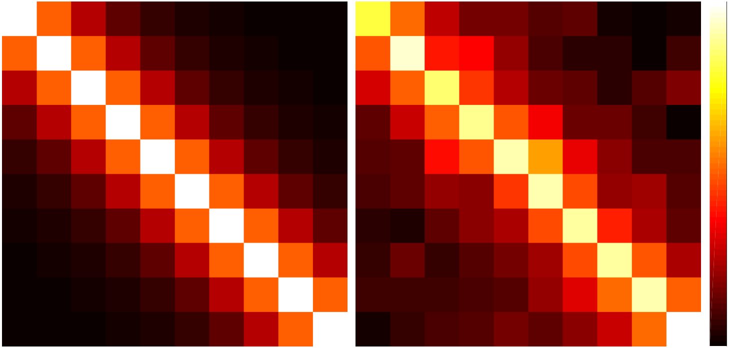
$$R_i = 1 - S_i - E_i - I_i$$



Isolated



Nearest Neighbour



Exponential Cooling

Making Waves

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$$\frac{dS_i}{dt} = -\beta_i S_i I_i \left(1 - \phi \frac{M}{M+1}\right) - \frac{\phi}{M+1} \sum_{j=1}^{M} \beta_{ij} I_j$$

$$\frac{dI_i}{dt} = \beta_i S_i I_i \left(1 - \phi \frac{M}{M+1}\right) + \frac{\phi}{M+1} \sum_{j=1}^{M} \beta_{ij} I_j - \gamma I_i$$

$$\frac{dR_i}{dt} = \gamma I_i$$

$$+$$

$$\beta_{i,t+1} = \bar{\beta}_i + \eta(\beta_{i,t} - \bar{\beta}_i) + \epsilon_{i,t}$$

$$\frac{dS_i}{dt} = -\beta_i S_i I_i \left(1 - \phi \frac{M}{M+1}\right) - \frac{\phi}{M+1} \sum_{j=1}^{M} \beta_{ij} I_j$$

$$\frac{dI_i}{dt} = \beta_i S_i I_i \left(1 - \phi \frac{M}{M+1}\right) + \frac{\phi}{M+1} \sum_{j=1}^{M} \beta_{ij} I_j - \gamma I_i$$

$$\frac{dR_i}{dt} = \gamma I_i$$

$$+$$

$$\beta_{i,t+1} = \bar{\beta}_i + \eta(\beta_{i,t} - \bar{\beta}_i) + \epsilon_{i,t}$$

Animation!