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Power-law features in modelling the spatio-temporal spread of infectious diseases

Short-time human travel behaviour may be described by a power law with respect to distance x, i.e. $f(x) \propto x^{-d}$ with positive decay parameter d. We incorporate this information in space-time models for infectious disease surveillance data to better capture the dynamics of disease spread. Two previously established model classes are extended, which both decompose disease risk additively into an endemic and an epidemic component: a multivariate time series model for aggregated surveillance counts, and a space-time point process model for individual point-referenced data. In both frameworks, the power-law dispersal is embedded into the epidemic component and its decay parameter d is estimated simultaneously with all other unknown parameters using (penalised) maximum-likelihood inference. The performance of the new approach is investigated by a re-analysis of count data on influenza in Southern Germany (2001–2008) and individual cases of invasive meningococcal disease in Germany (2002–2008). In both applications, the power-law formulation substantially improves model fit and predictions. Implementation in the `R` package `surveillance` allows to apply the approach in other settings.

Key words: Power law; Distance decay function; Infectious disease surveillance; Stochastic epidemic modelling.