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A three-variable chaotic system for the epidemic of bubonic plague in Bombay by the end of the 19th century and its coupling to the epizootics of the two main species of rats

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A plague epidemic broke out in Bombay by the end of the 19th century. A committee was first appointed by the Bombay City [1] in order to stop the epidemic before the rain season started. Unfortunately, the disease could not be stopped and the epidemic became endemic. After several years, another Advisory Committee [2] was appointed that tried to investigate the causes of plague in all possible directions. An impressing quantity of information was gathered during the period 1907-1911 and published. In particular, it was noticed that the epidemic was systematically preceded by epizootics of rats. For this reason, the populations of the main species of rodents were systematically monitored.
This data set is revisited here by using a multivariate version of the global modeling technique [3]. The aim of this technique is to obtain a set of Ordinary Differential Equations directly from time series. Three observational time series are considered: the number of person died of bubonic plague per half month (1), and the number of captured infected black rats Mus rattus (2) and brown rats Mus decumanus (3). Several models are obtained, all based on the same algebraic basic structure. These models are, either directly chaotic, or close to chaos (chaos could easily be obtained by tuning one model parameter). The algebraic structure of the simplest model obtained is analyzed in more details. Surprisingly, it is found that the interpretation of the coupling between the three variables can be done term by term. This interpretation is in quite good coherence with the conclusions of the Advisory Committee published one hundred years ago. This structure also shows that the human action to slow down the disease during this period was obviously effective, although insufficient to stop the epidemic drastically.
This result suggests that the global modeling technique can be a powerful tool to detect causal couplings in epidemiology, and, more generally, among observational variables from any dynamical networks. The possibility to apply the technique to other diseases (such as Ebola) and to detect couplings to climatic conditions will also be evoked.

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