

Infectious diseases: time, space and control

Marc Choisy

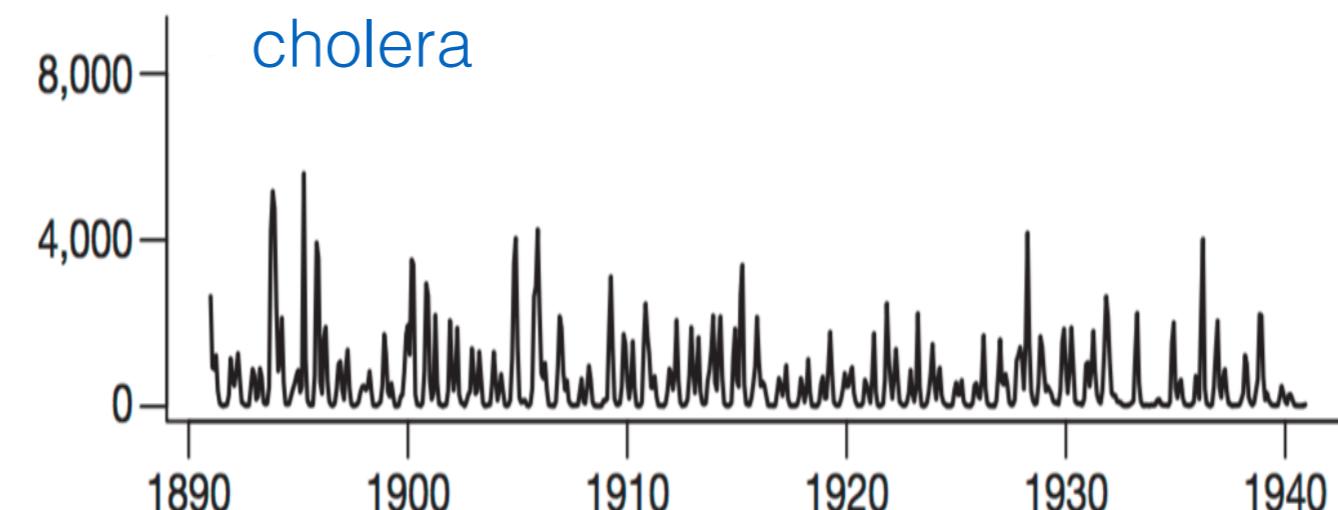
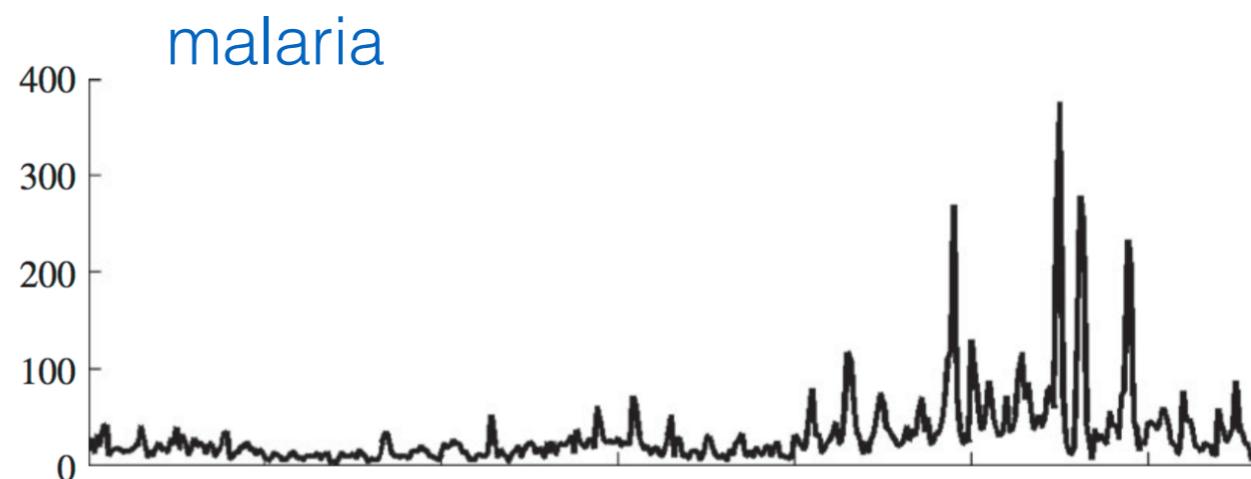
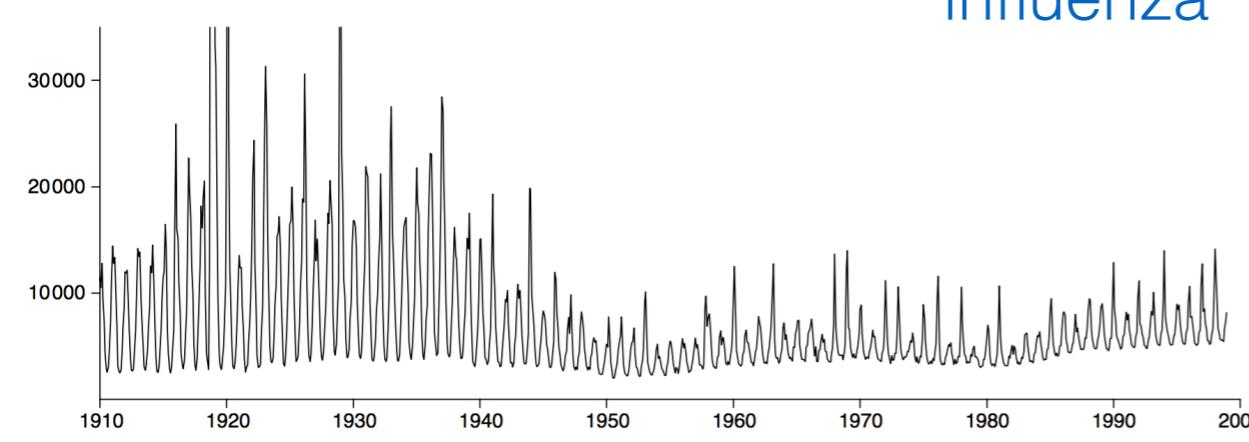
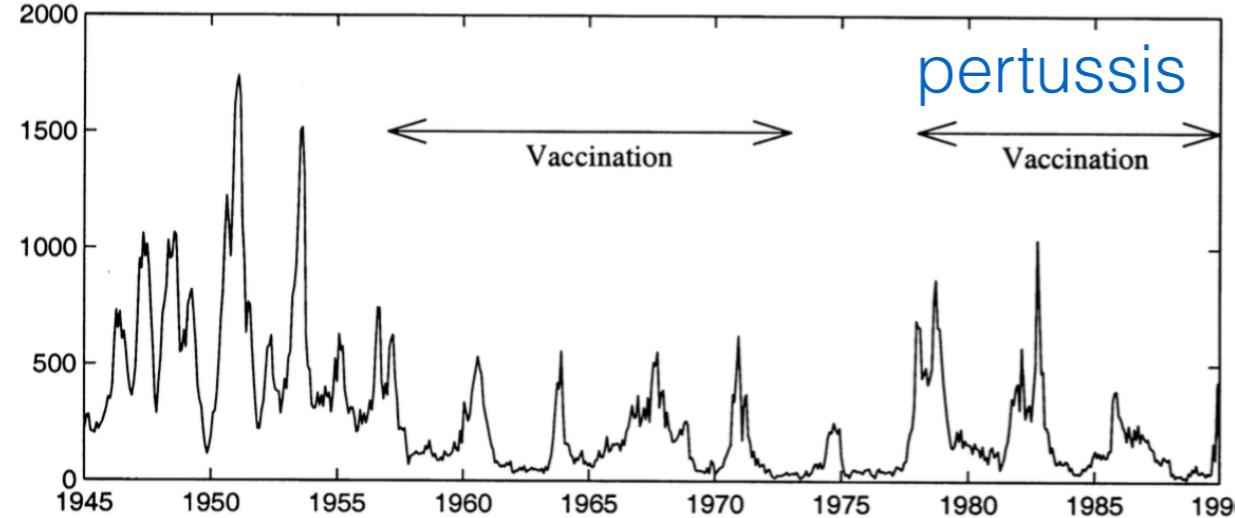
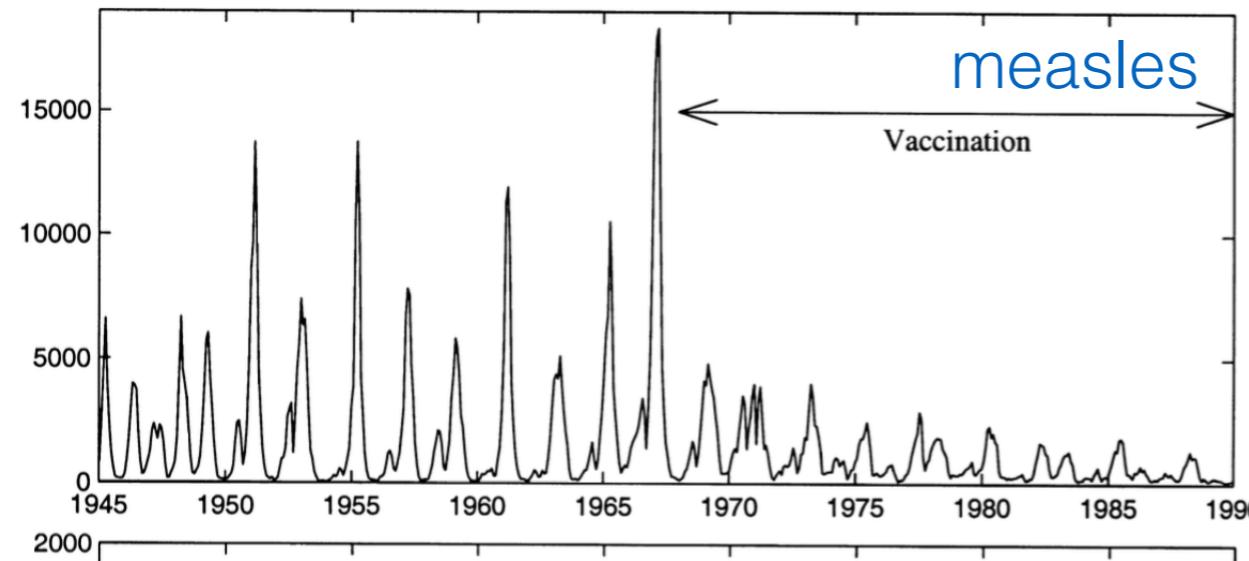


Seasonality

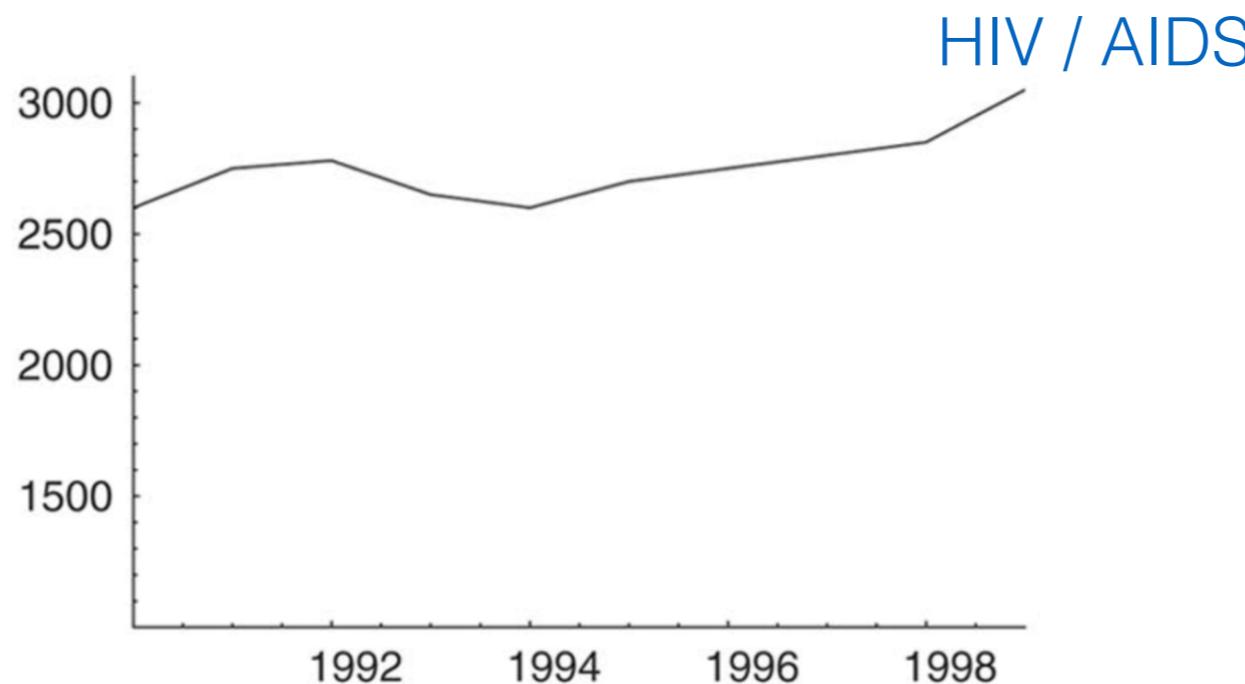
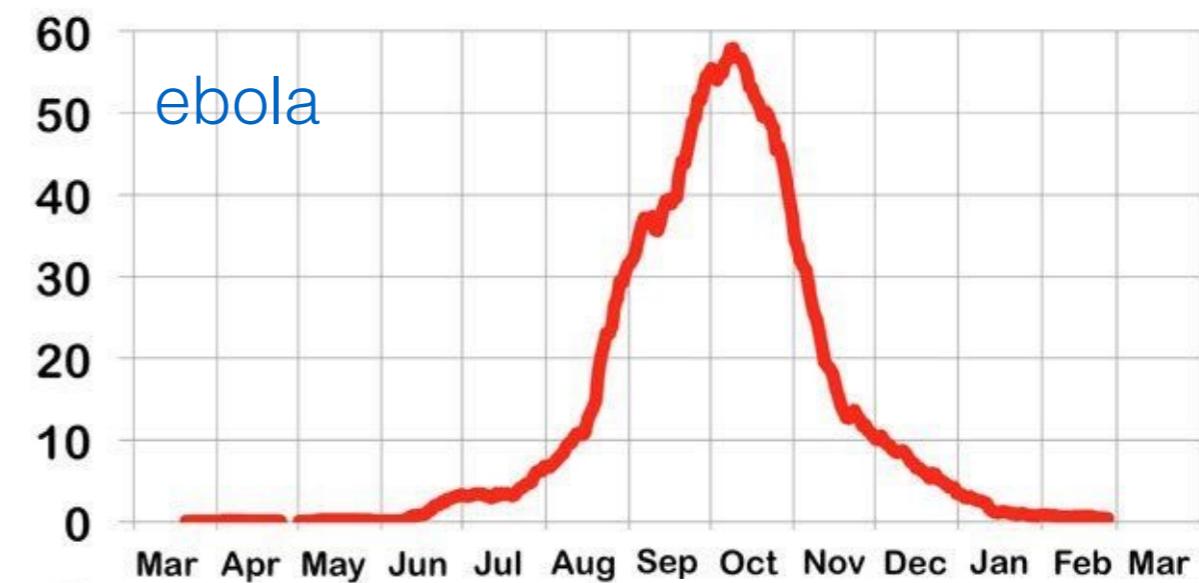
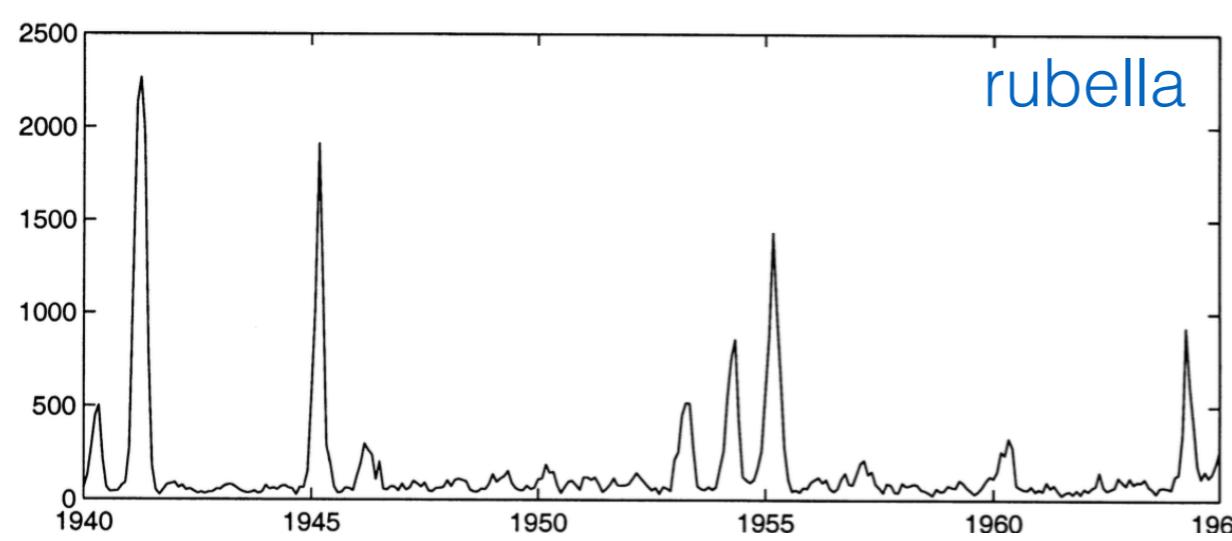
Spatial dynamics

Optimal control

Seasonality of infectious diseases



Seasonality of infectious diseases



Seasonality of infectious diseases

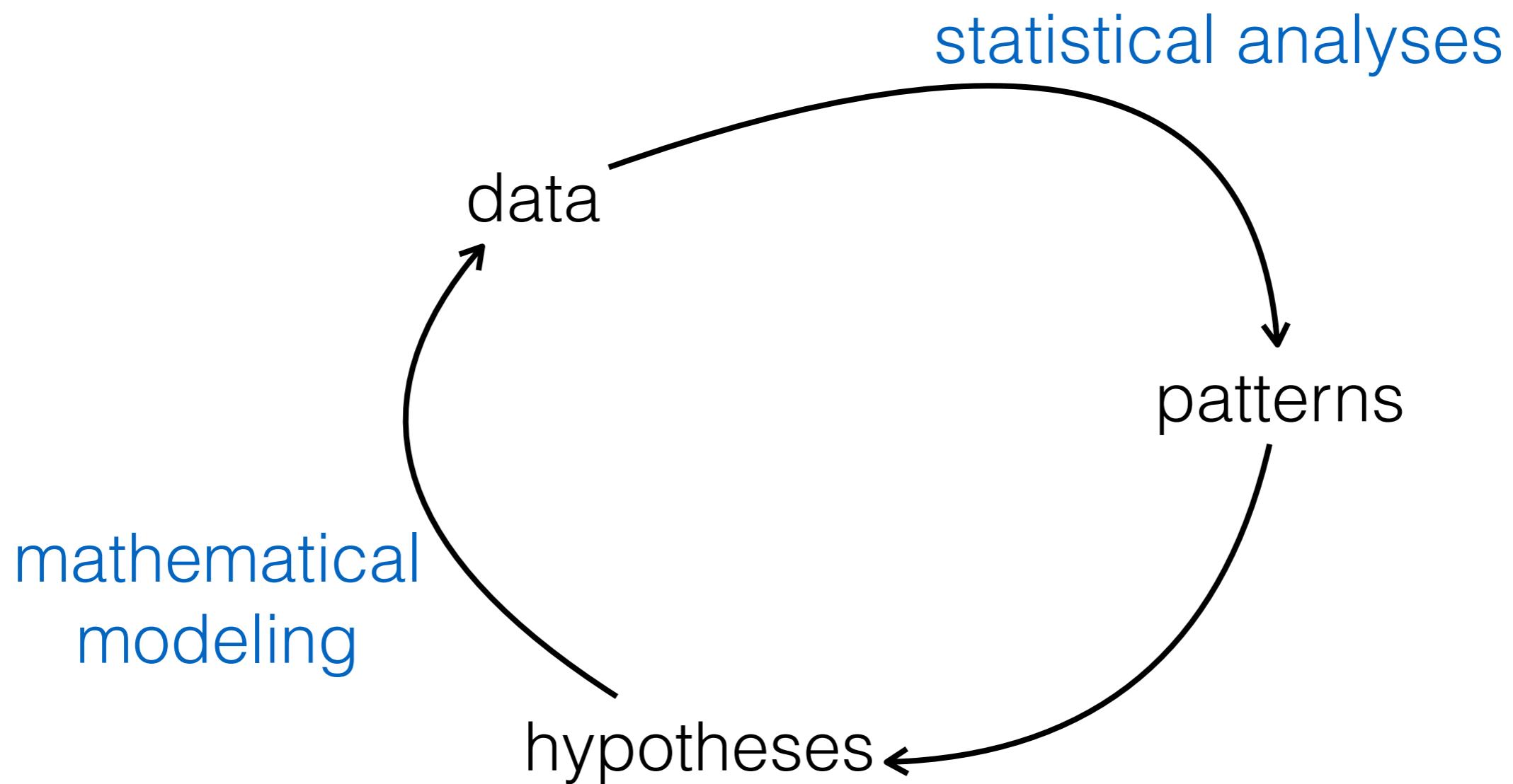
Why studying seasonality?

- can help forecasting
- can affect persistance

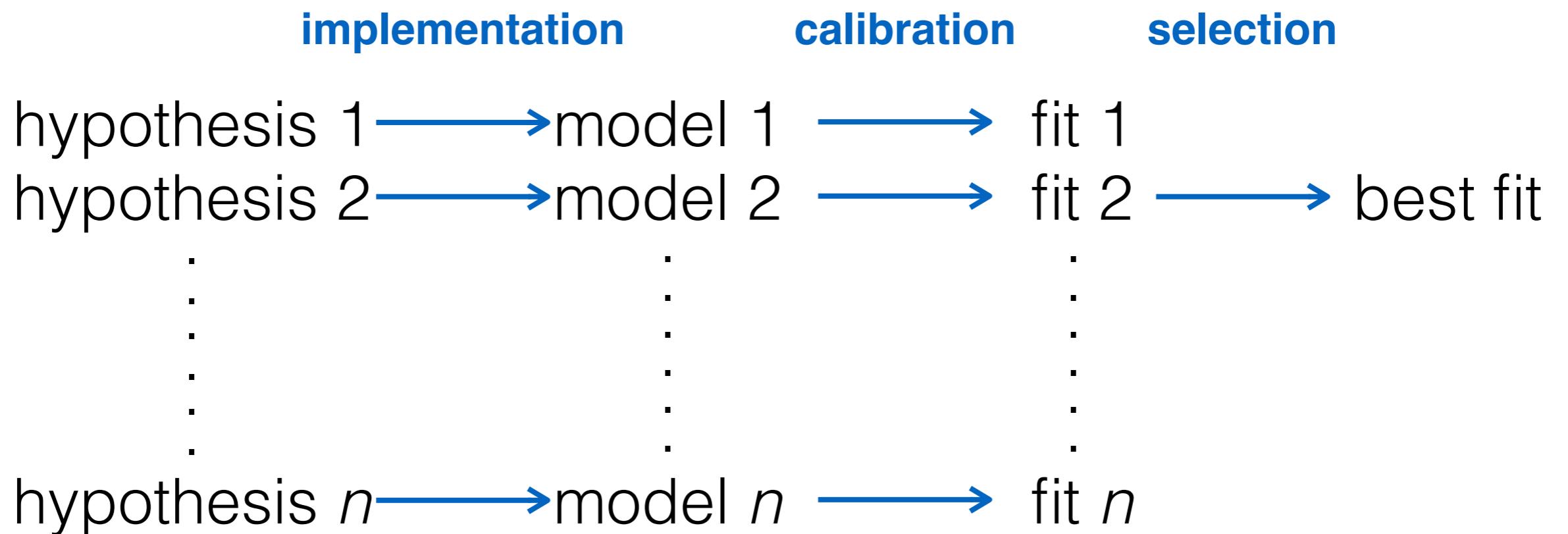
How to study seasonality?

- signal processing to unravel patterns
- testing hypotheses on mechanisms
 - natural experiments
 - competing hypotheses

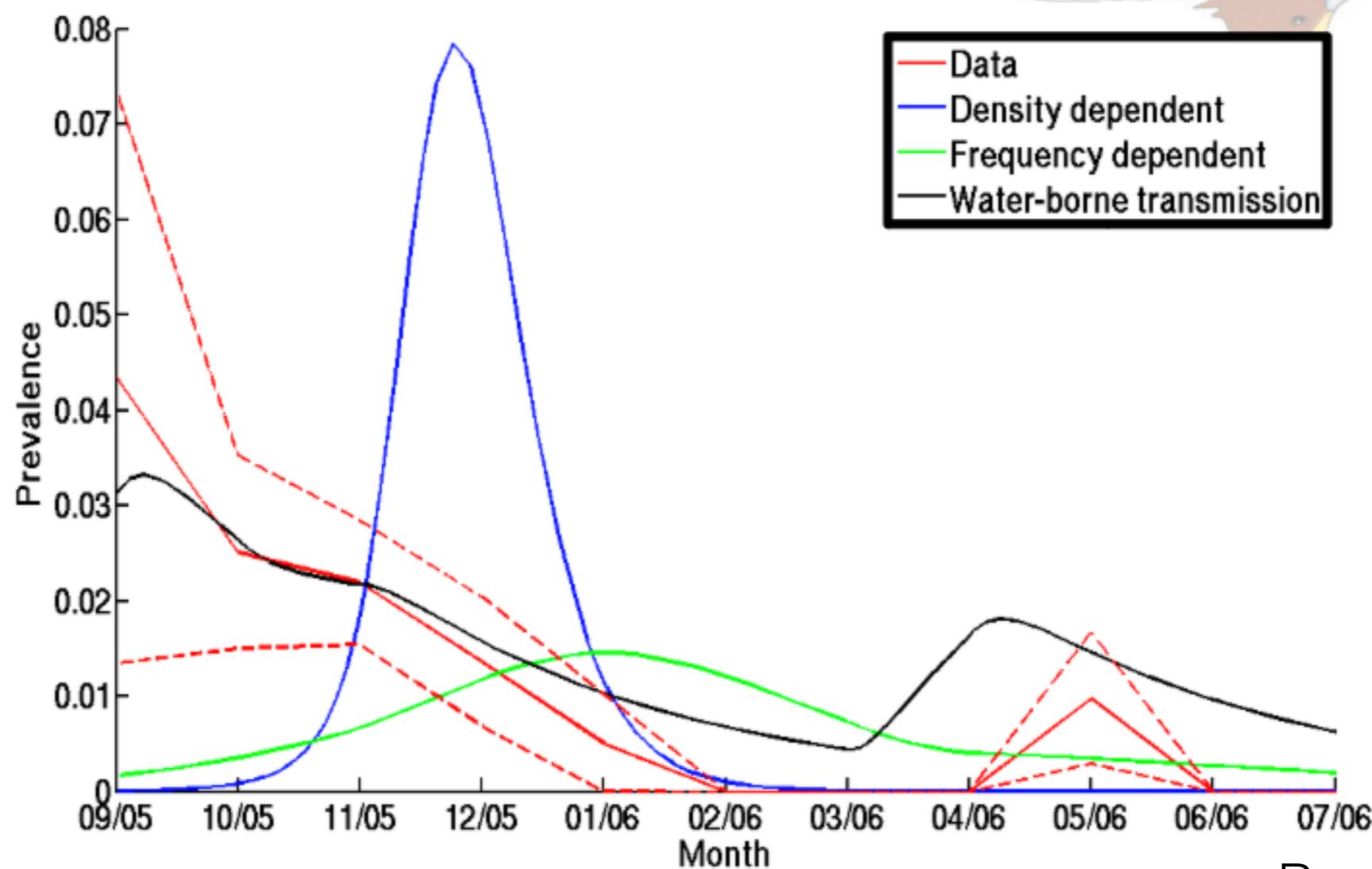
Seasonality of infectious diseases



Testing hypotheses: Competing models

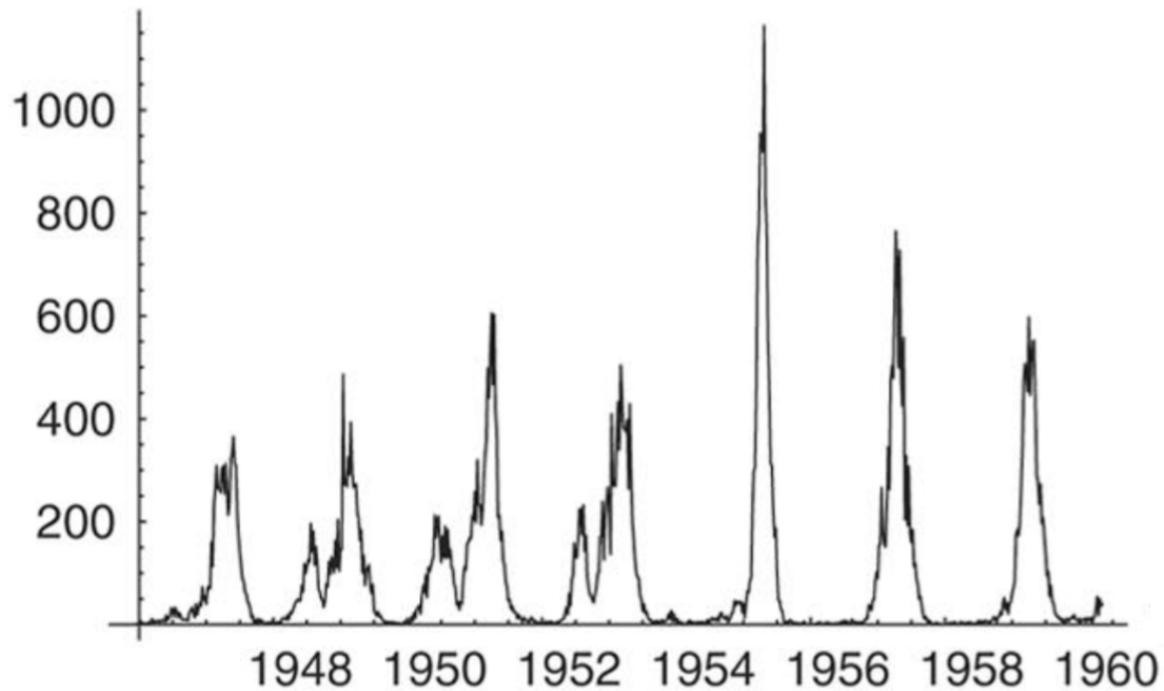


Testing hypotheses: Competing models

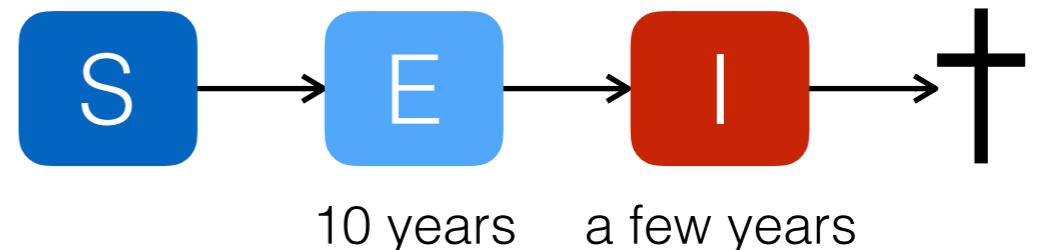
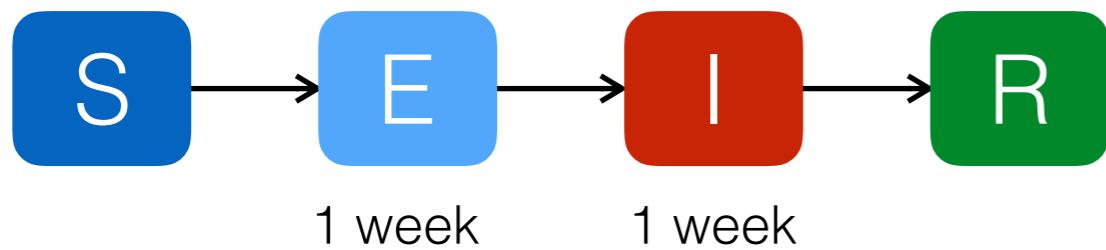
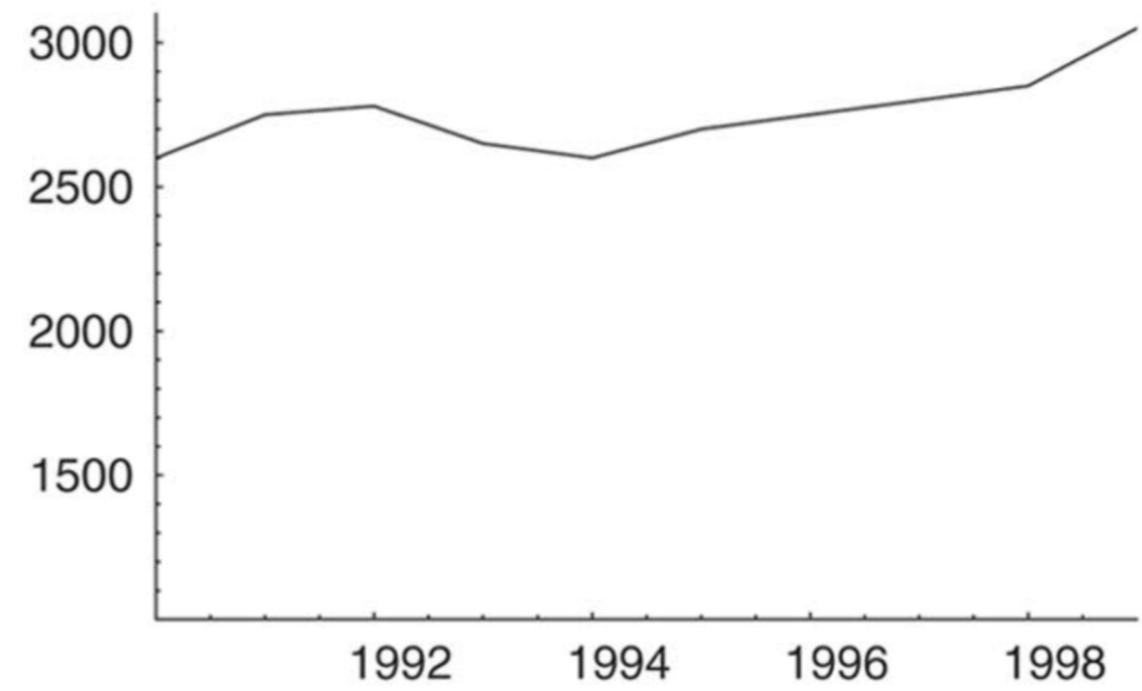


Causes of seasonality: Intrinsic epidemiological dynamics

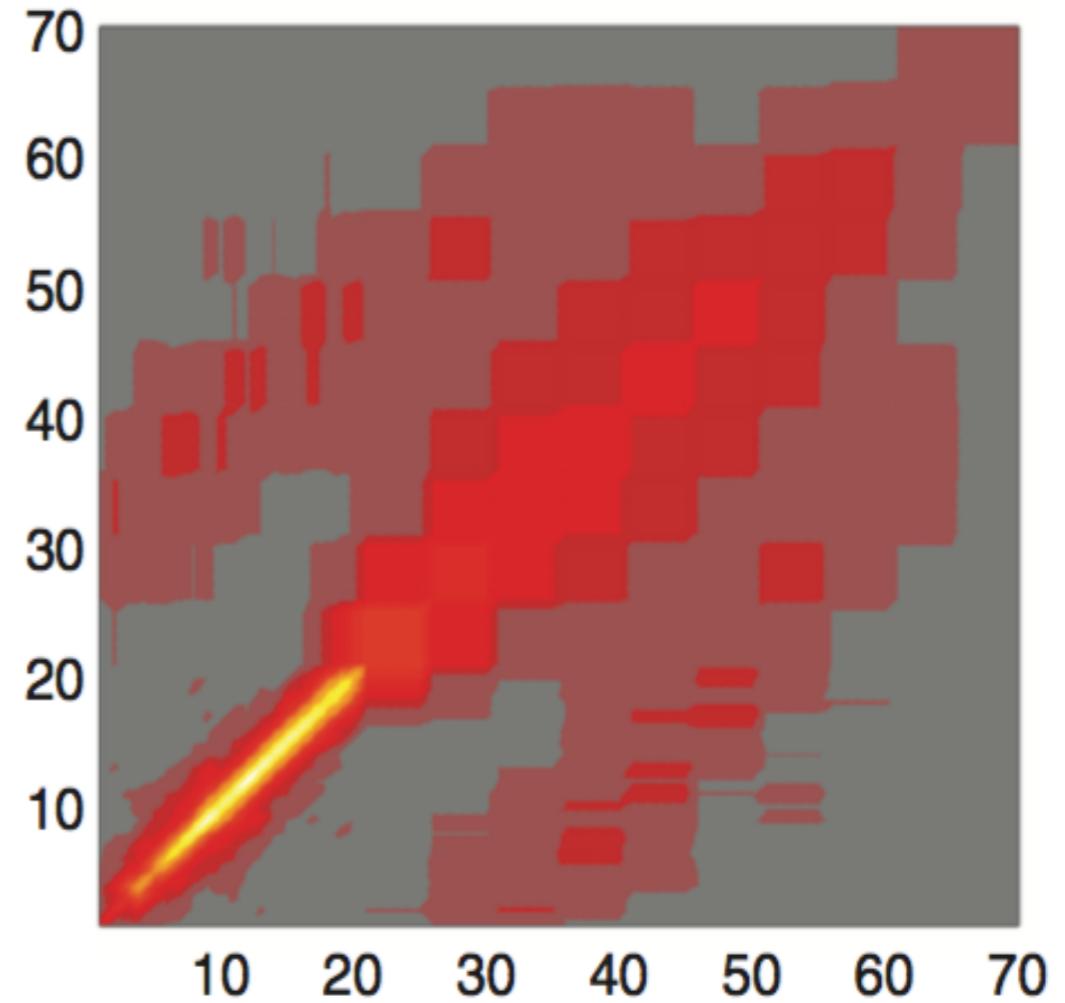
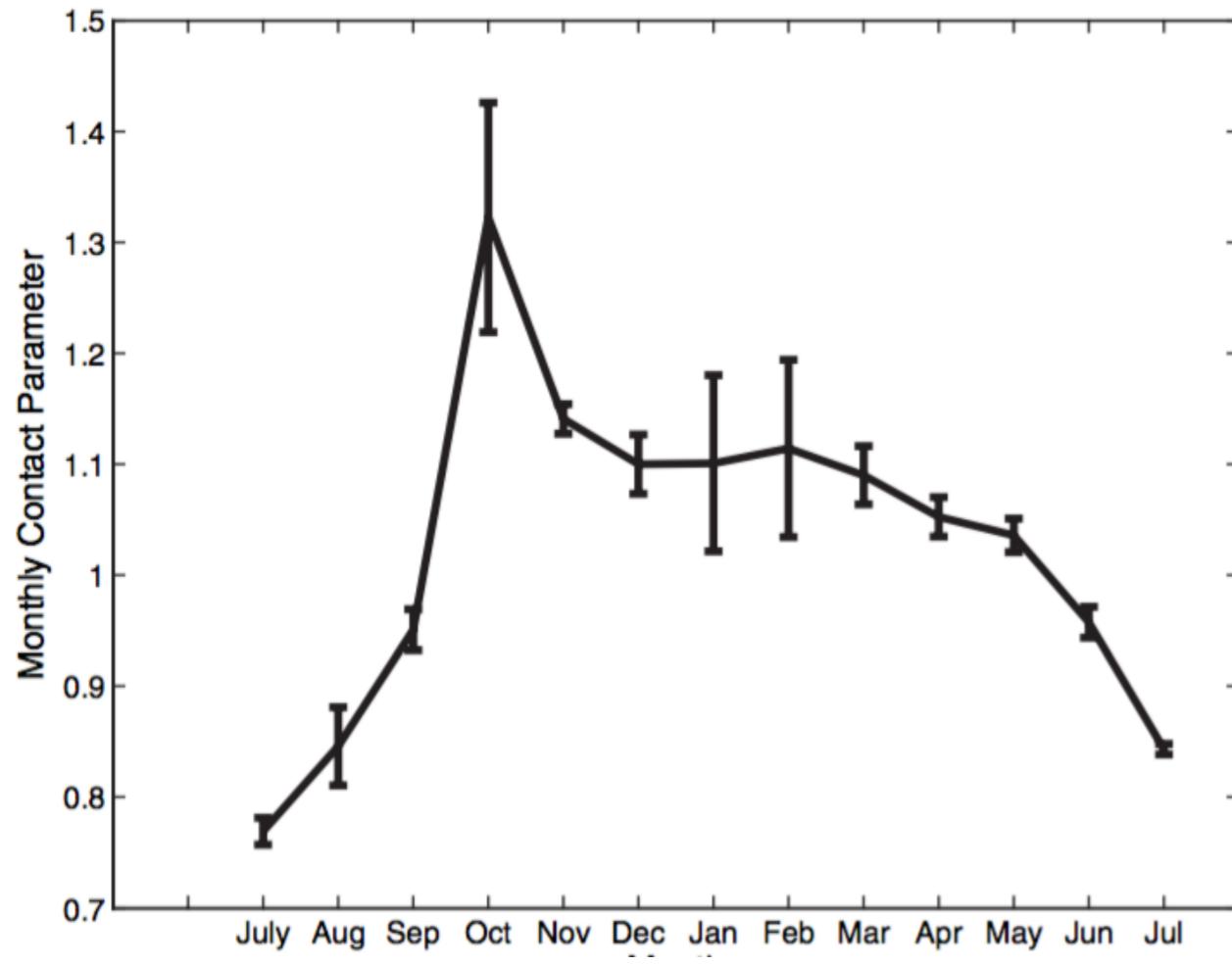
measles



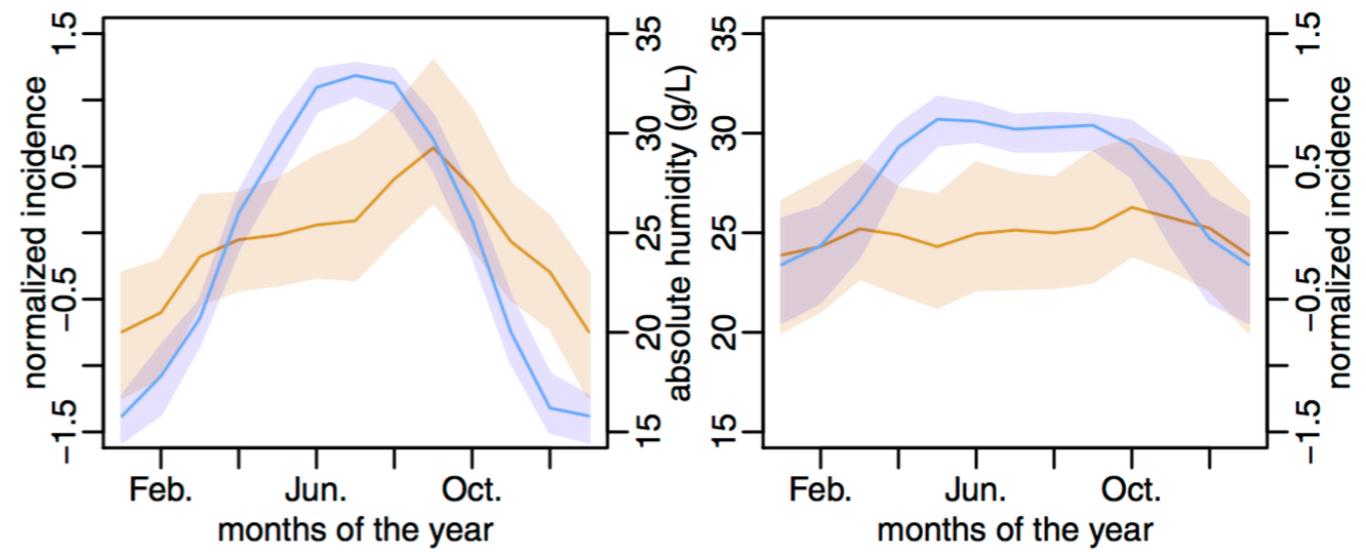
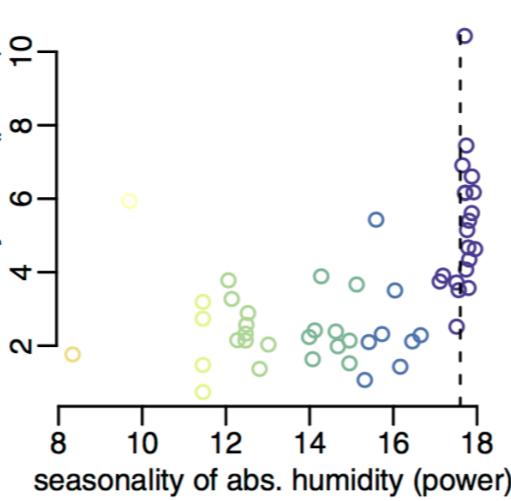
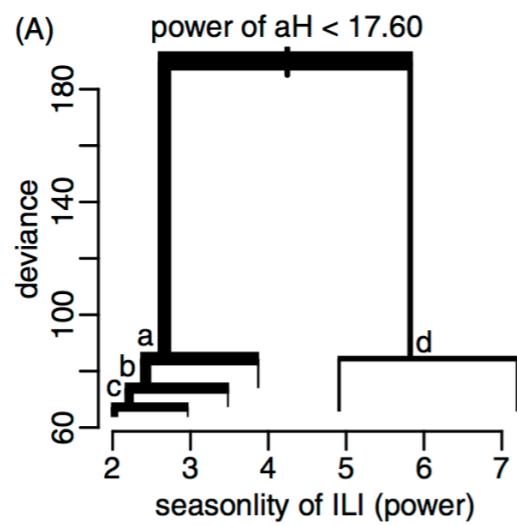
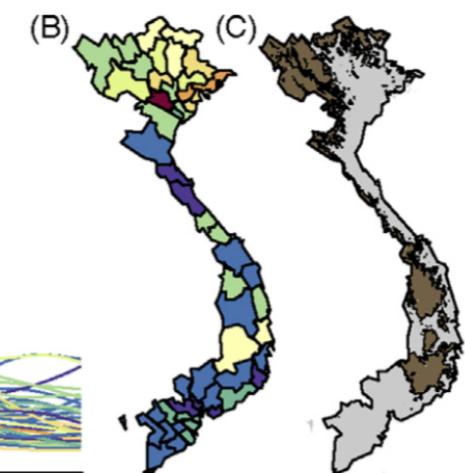
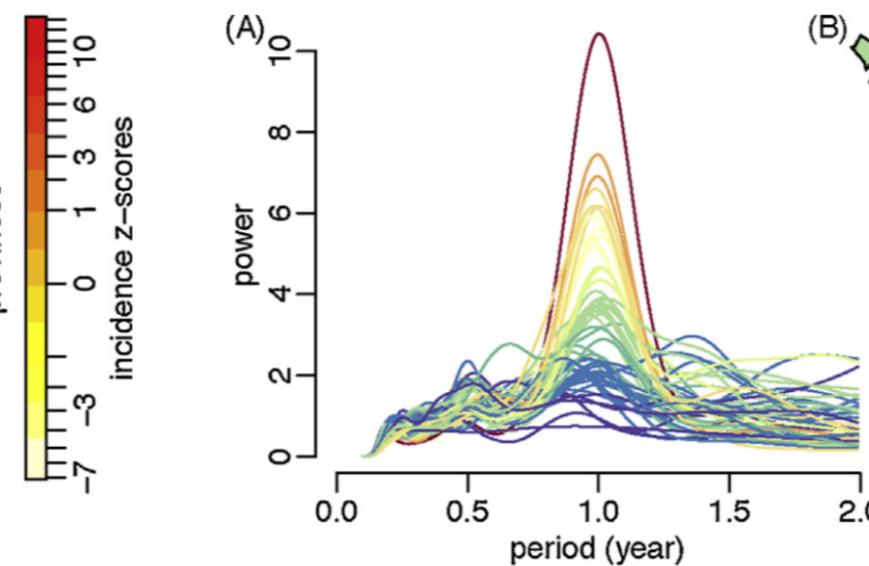
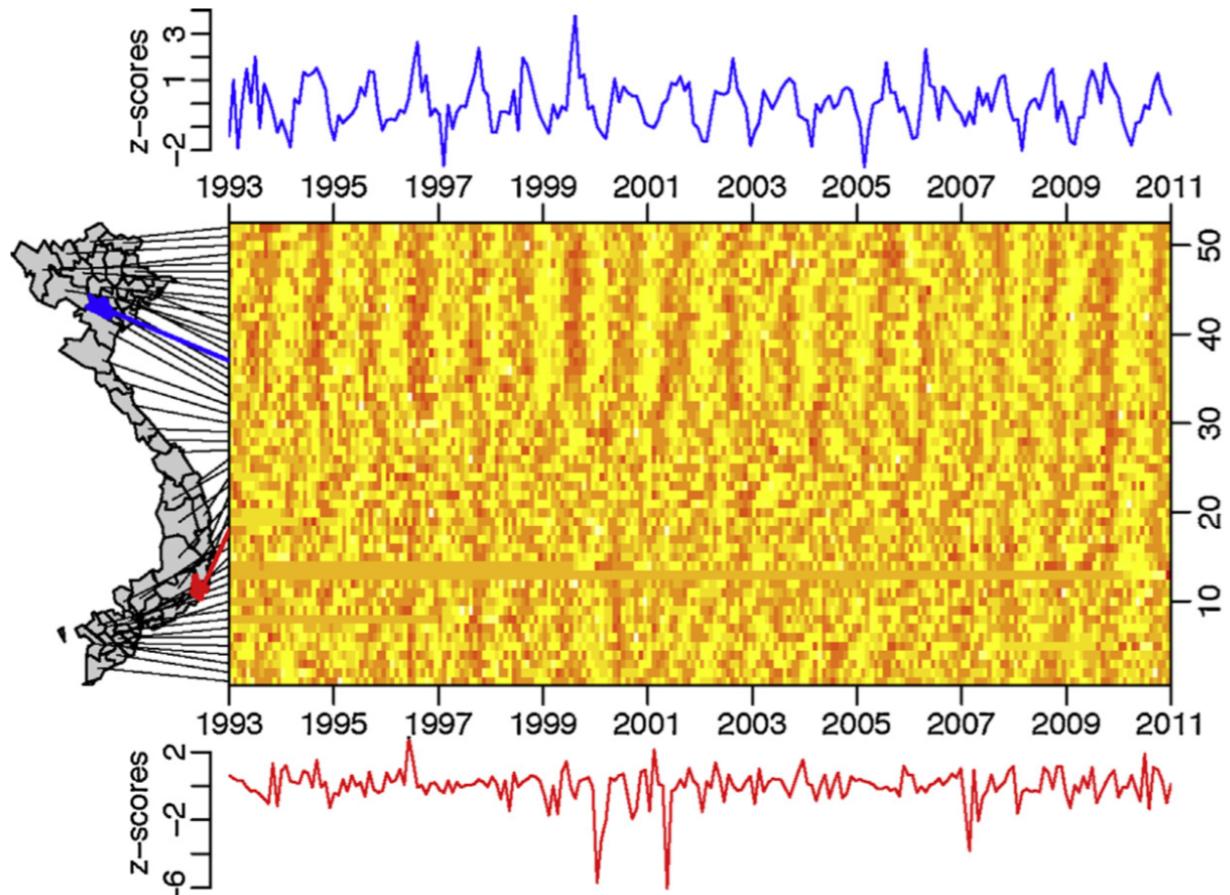
HIV / AIDS



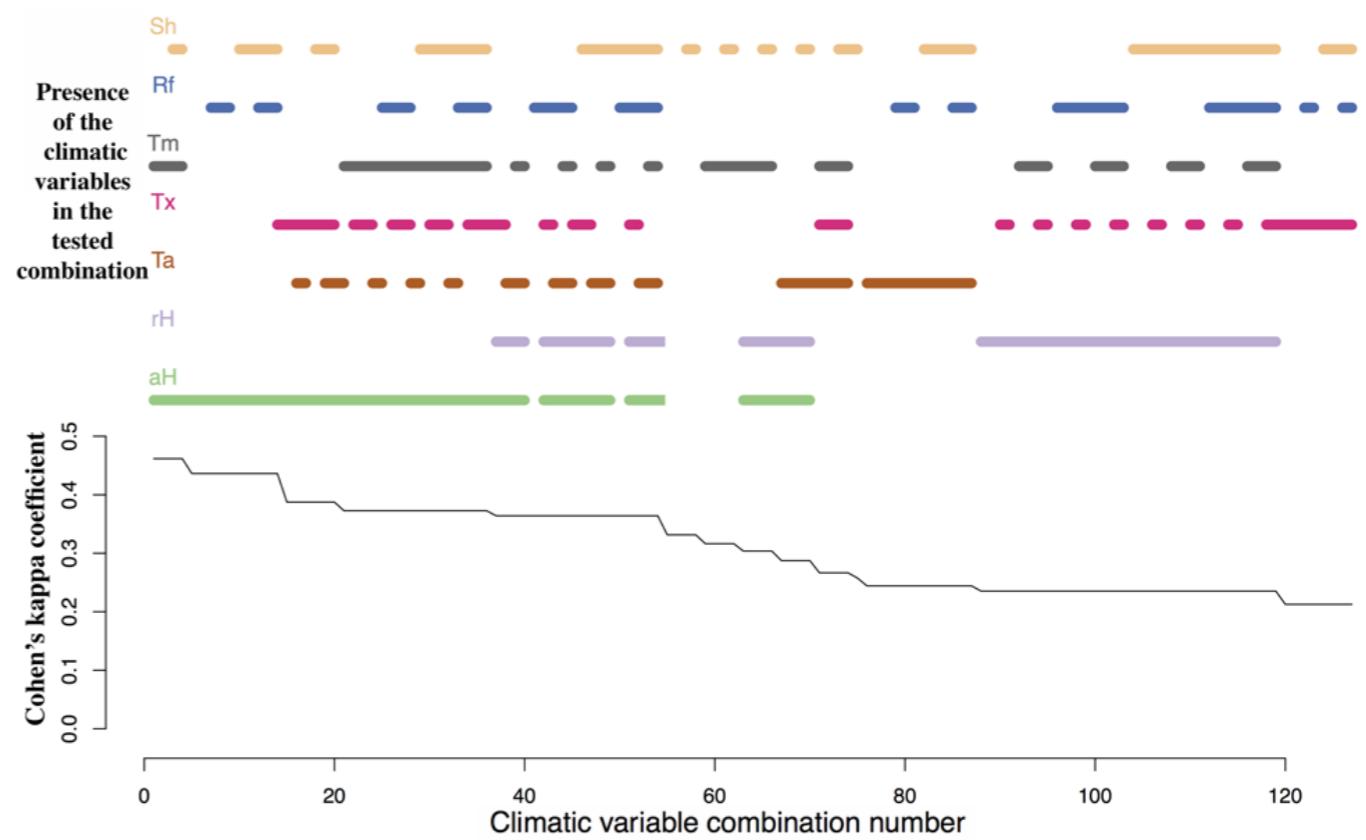
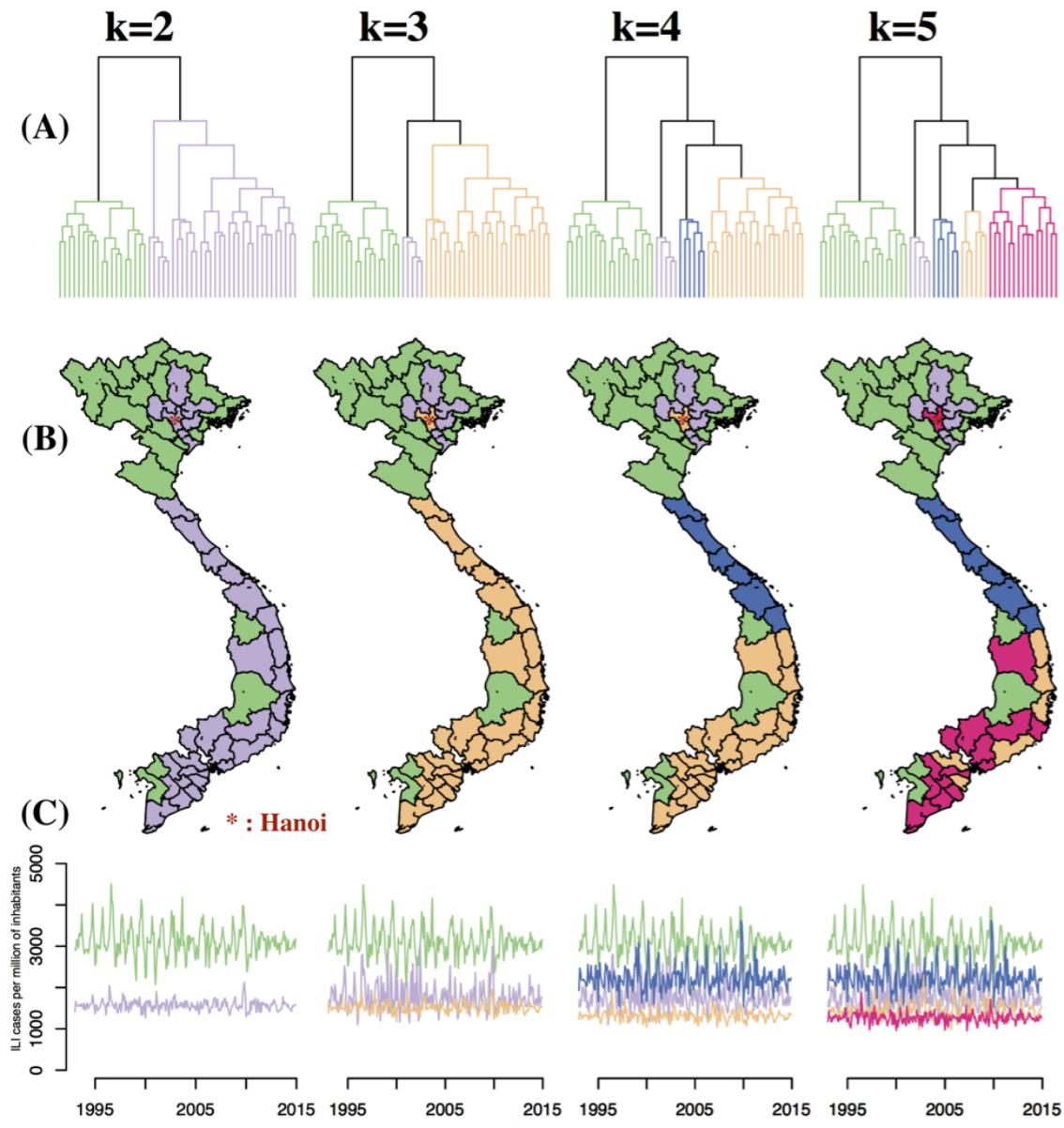
Causes of seasonality: sociology



Causes of seasonality: meteorology



Causes of seasonality: meteorology



Seasonality of infectious diseases

Why cause seasonality?

- intrinsic epidemiological dynamics
- demography
- sociology / behaviors
- immunology / evolution
- meteorology
- entomology
- etc...

Seasonality of infectious diseases

The figure displays three academic papers from PLOS Medicine and PNAS, each with a large red stamp across it:

- PLOS Medicine Paper 1:** Nonstationary Influence of El Niño on the Synchronous Dengue Epidemics in Thailand. Authors: Bernard Cazelles, Mario Chavez, Anthony J. McMichael, Simon Hales. DOI: 10.1371/journal.pmed.0020106. This paper discusses the impact of El Niño on dengue epidemics in Thailand, showing that while El Niño events are associated with increased dengue incidence, they do not necessarily cause outbreaks. The stamp reads "Climate".
- PLOS Medicine Paper 2:** The Impact of the Demographic Transition on Dengue in Thailand: Insights from a Statistical Analysis and Mathematical Modeling. Authors: Derek A. T. Cummings, Sopon Iamthirithaworn, Justin T. Lessler, Aidan McDermott, Rungnapa Prasanthong, Ananda Nisalak, Richard G. Jarman, Donald S. Burke, Robert V. Gibbons. DOI: 10.1371/journal.pmed.0020139. This paper explores the relationship between demographic transitions and dengue incidence in Thailand, using statistical analysis and mathematical modeling. The stamp reads "demography".
- PNAS Paper:** Ecological and immunological determinants of dengue epidemics. Authors: Helen J. Wearing, Pejman Rohani. DOI: 10.1073/pnas.0602960103. This paper discusses the ecological and immunological factors that determine dengue epidemics, including the role of mosquito density, human population density, and antibody-dependent enhancement. The stamp reads "serotypes".

Abstracts and Key Findings:

- PLOS Medicine Paper 1:** Discusses the nonstationary influence of El Niño on dengue epidemics in Thailand, noting that while El Niño events are associated with increased dengue incidence, they do not necessarily cause outbreaks.
- PLOS Medicine Paper 2:** Shows that the demographic transition in Thailand has reduced dengue transmission and lengthened the interval between large epidemics.
- PNAS Paper:** Finds that antibody-dependent enhancement (ADE) is a key mechanism for dengue epidemics, where cross-reactive antibodies stimulate a prior infection wane to levels that no longer neutralize the heterotypic virus. This leads to a second episode of infection with a heterotypic dengue virus, which may lead to a process known as antibody-dependent enhancement (ADE; refs. 15–17). ADE occurs when cross-reactive antibodies stimulated by a prior infection wane to levels that no longer neutralize the heterotypic virus. Instead of preventing infection, the binding of antibody to virus at subneutralizing concentrations can result in enhanced viral replication by increased infection of cells bearing the IgG receptor (11). The presence of nonneutralizing antibody levels is also thought to be temporary, although how long such levels persist is unknown.

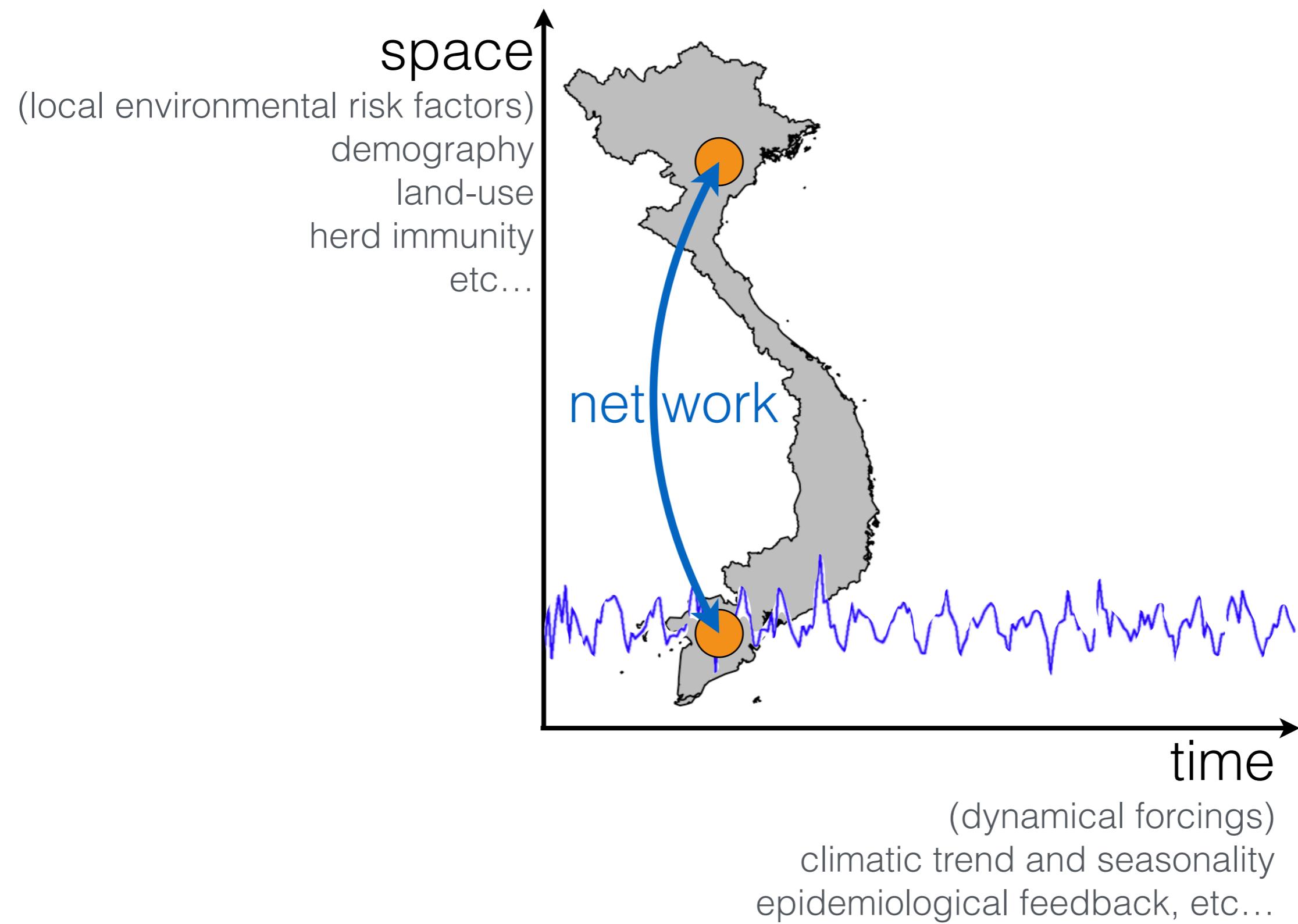
Seasonality

Spatial dynamics

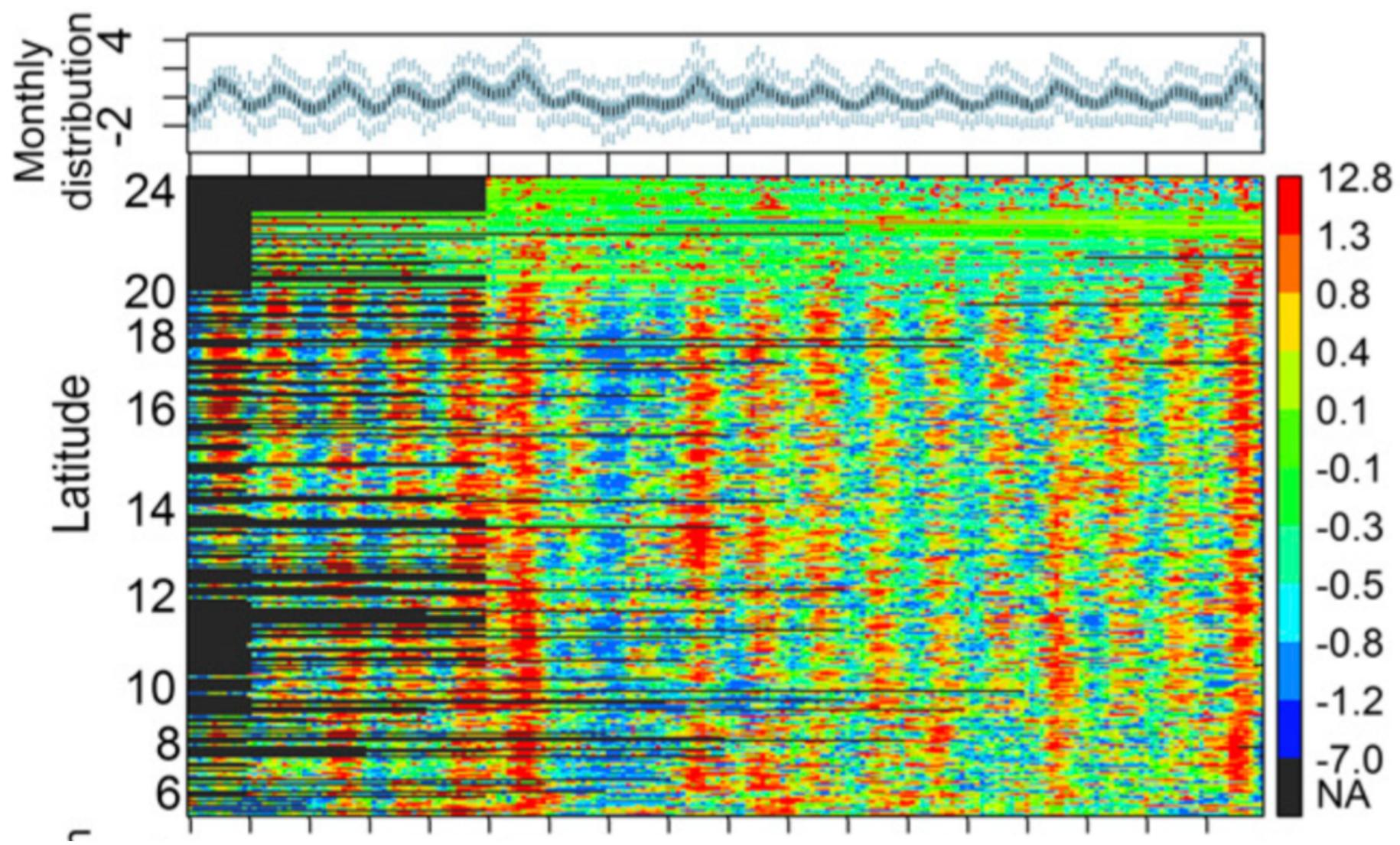
Optimal control

Model & data

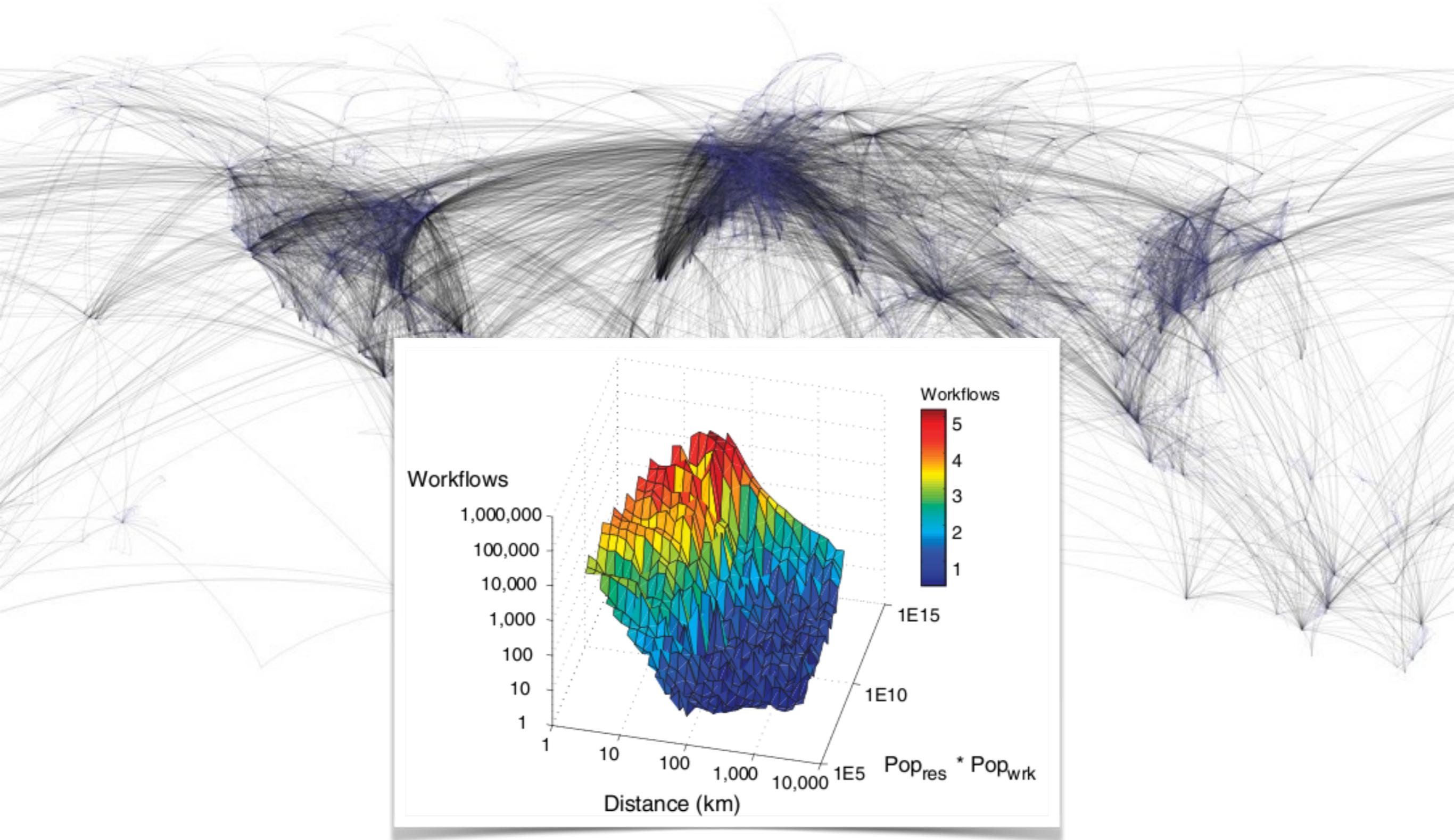
Local risk factors and movements



Adding the spatial dimension

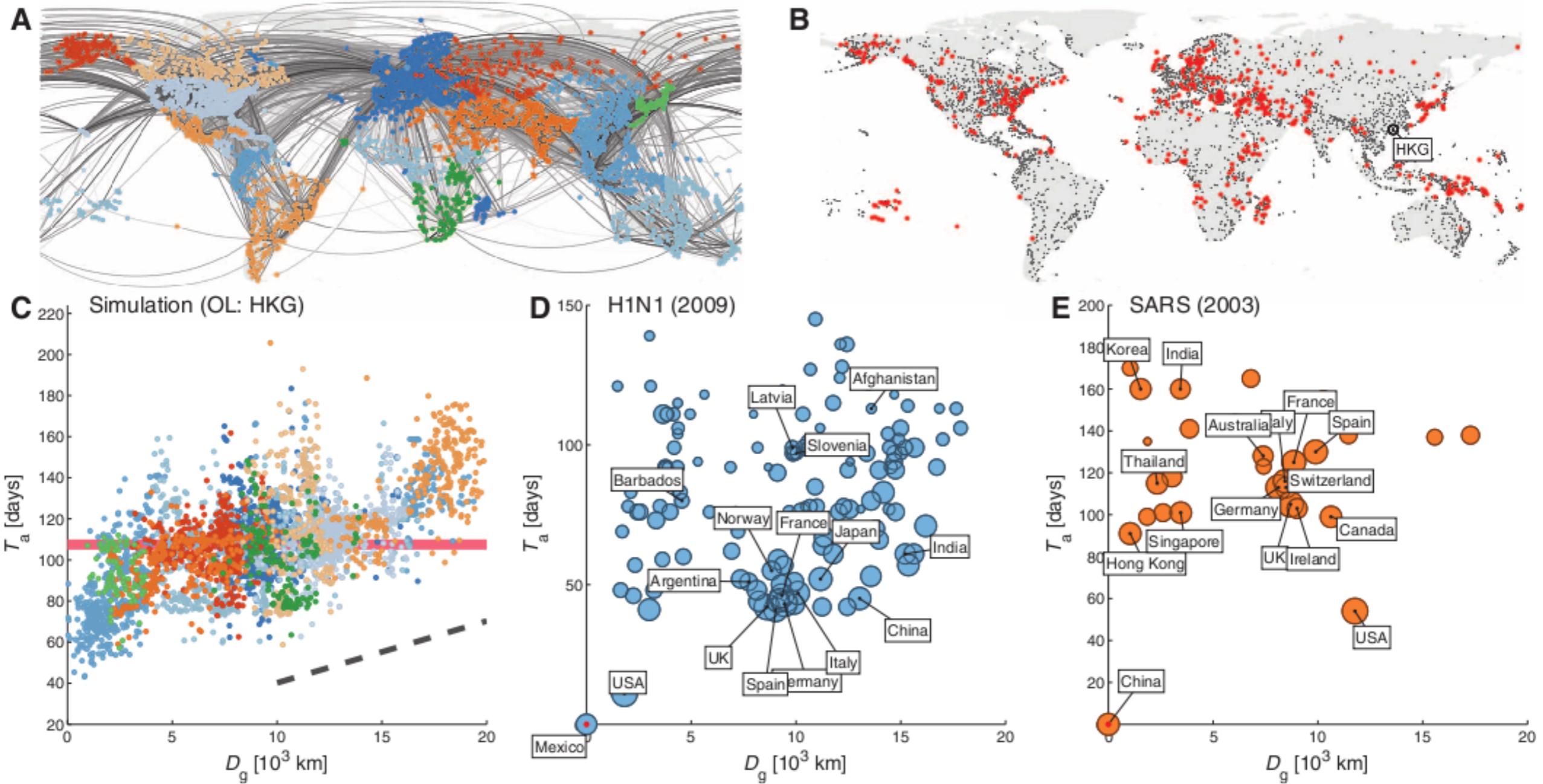


Connections between populations

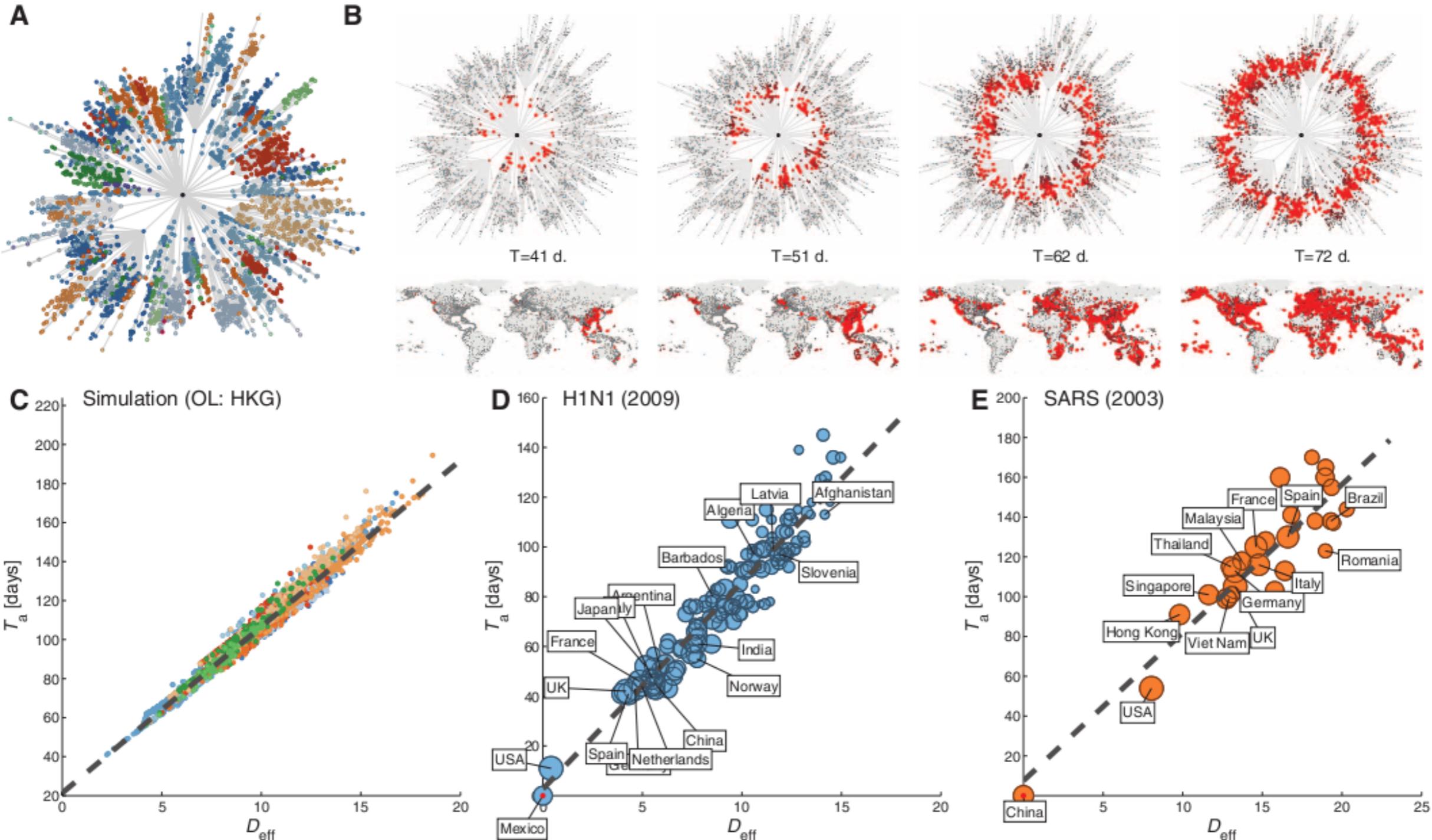


Xia et al. 2004, Viboud et al. 2006

Redefining distances



Redefining distances

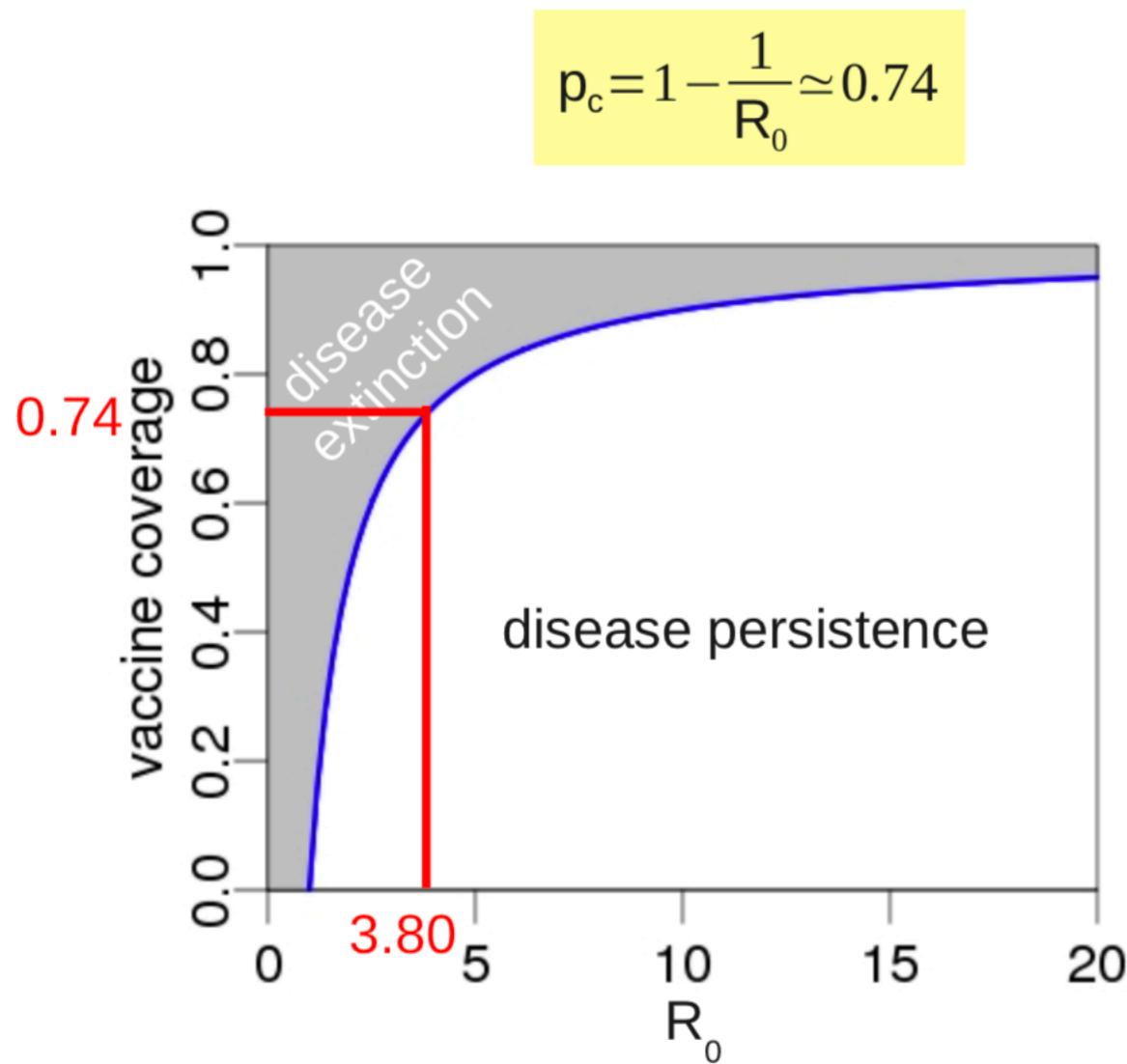


Seasonality

Spatial dynamics

Optimal control

Herd immunity



herd immunity



$$R_0 = \frac{\beta}{\gamma} = \frac{1.67}{0.44} = 3.80$$

Herd immunity

Disease	Host	R_0	p_c
tuberculosis	cattle	2.6	62%
FIV	domestic cat	1.1-1.5	9-33%
rabies	hyaenas	1.9	47%
phocine distemper	seals	2-3	50-66%
influenza	human	3-4	66-75%
foot and mouth disease	livestock	3.5-4.5	71-78%
smallpox	human	3.5-6	71-83%
rubella	human	6-7	83-86%
chickenpox	human	7-8 / 10-12	86-88% / 90-92%
Measles, whooping cough	human	16-18	94%
mumps	human	7-8 / 11-14	86-88% / 91-93%
rubeola	human	6-7 / 15-16	83-86% / 93-94%
HIV-AIDS	human	4 / 11	75 / 91%

ghed when

happy because
the corn field.

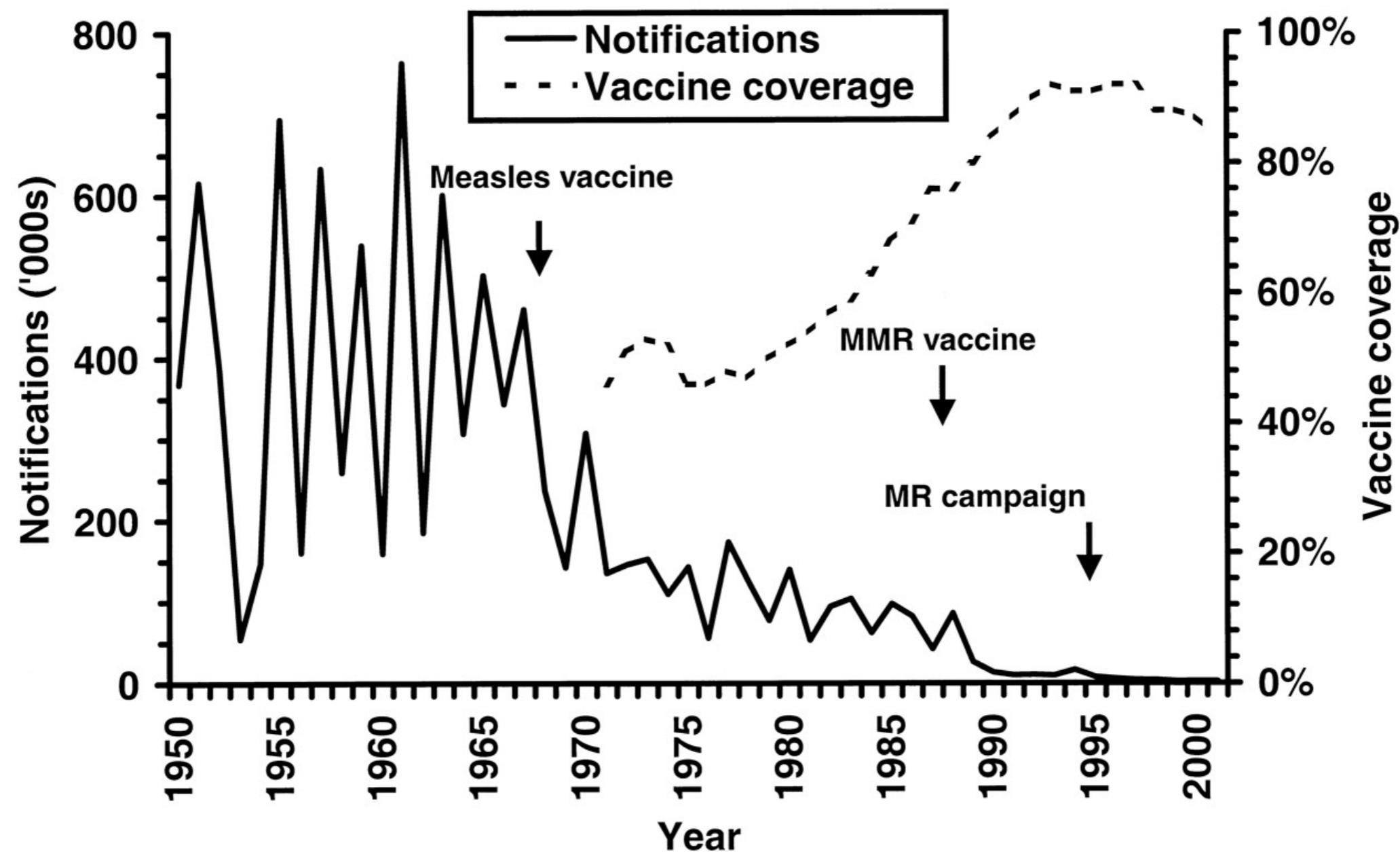
April 19, 1955

Making History.

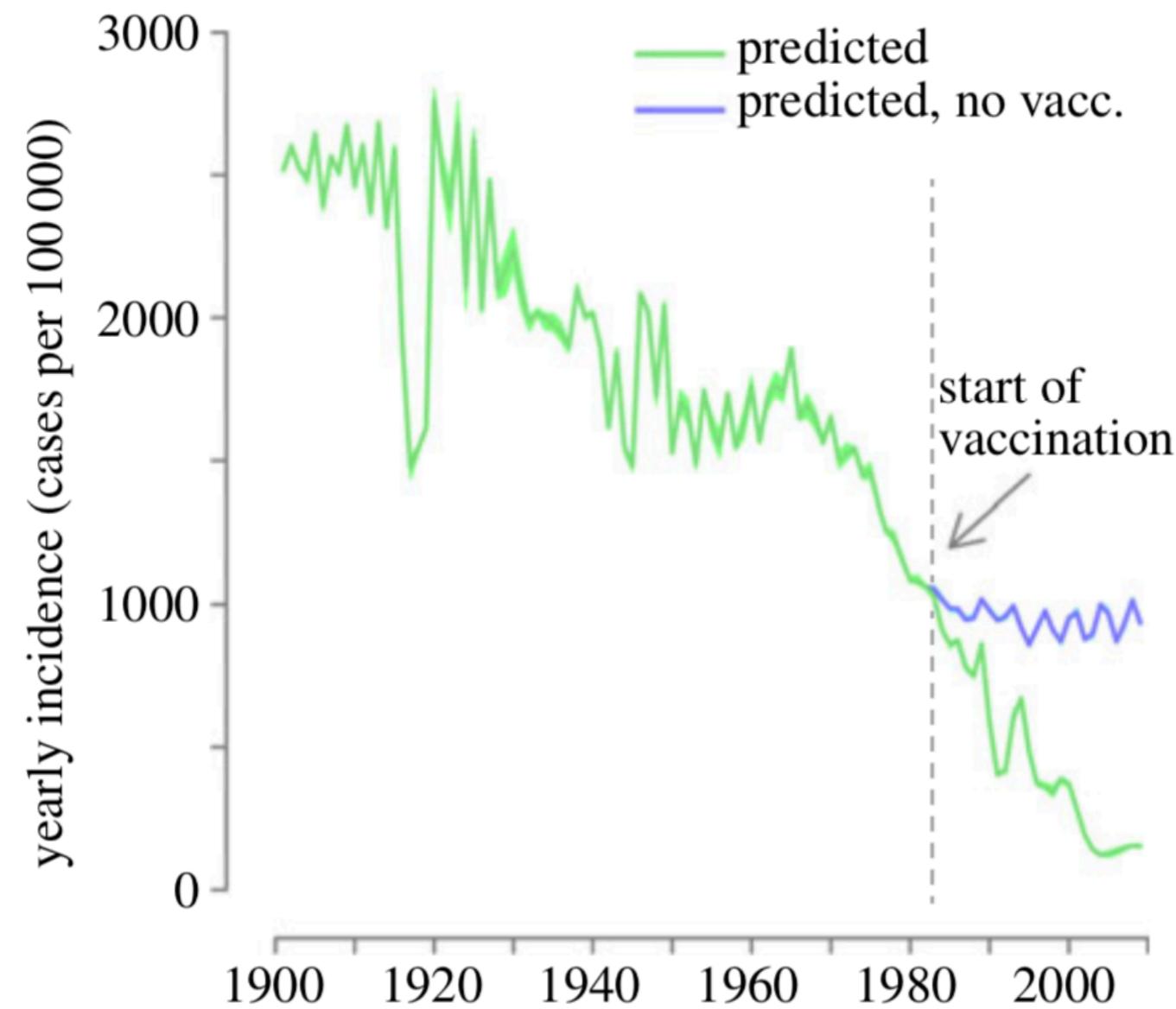
We are among the first children ever
to be given Polio shots. So we are really
making History today.
We are lucky.



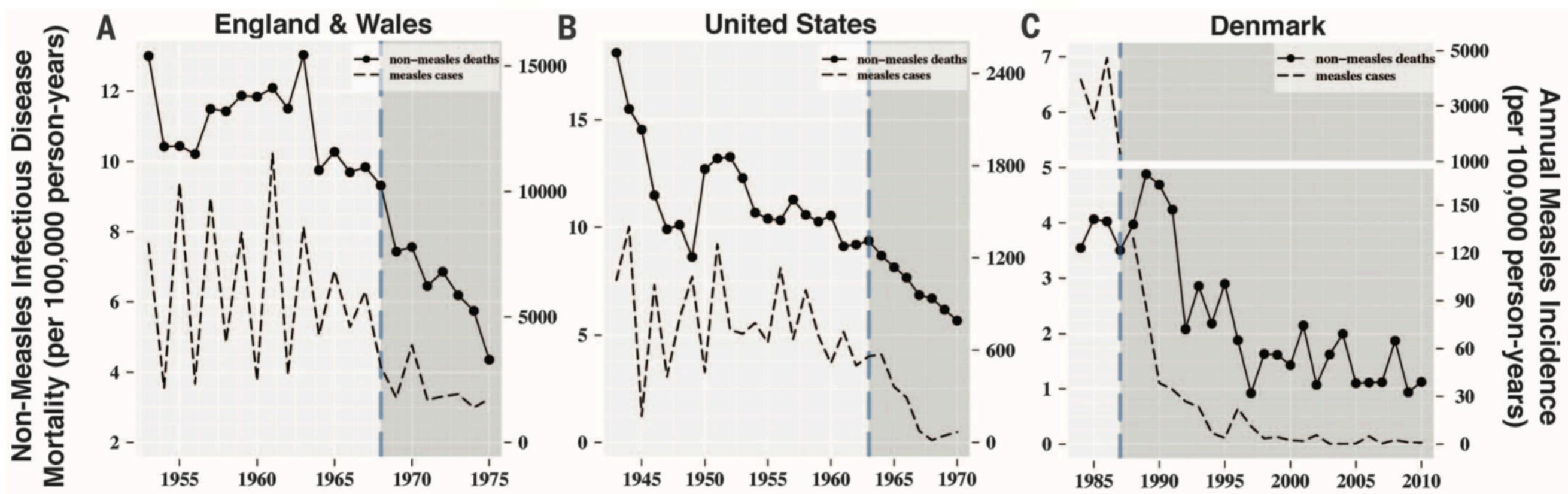
Vaccine policies: a success story



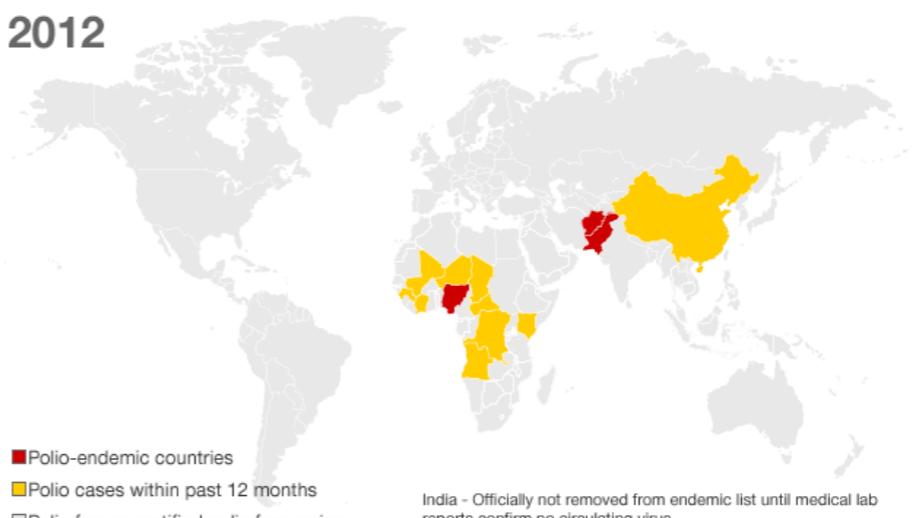
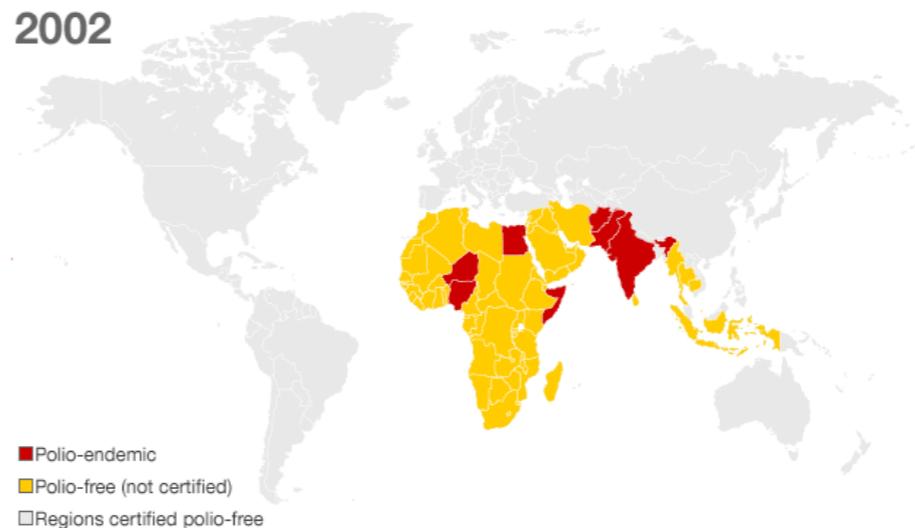
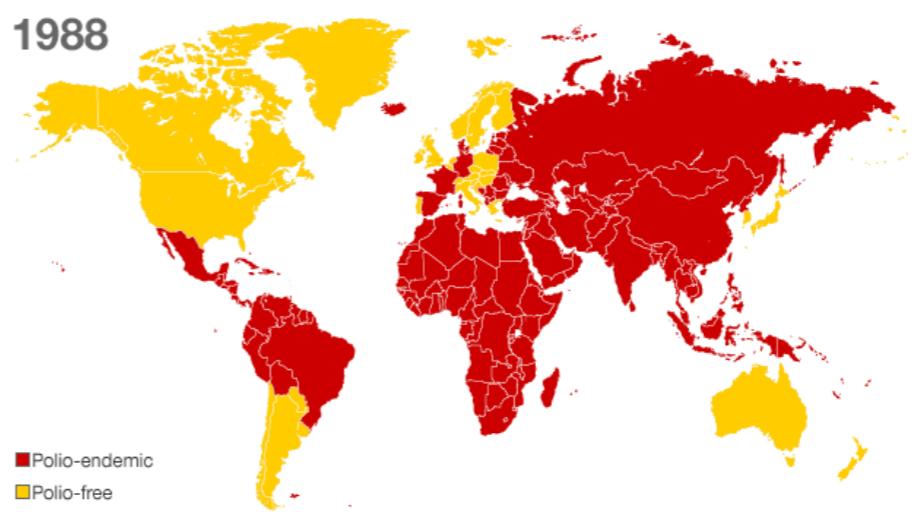
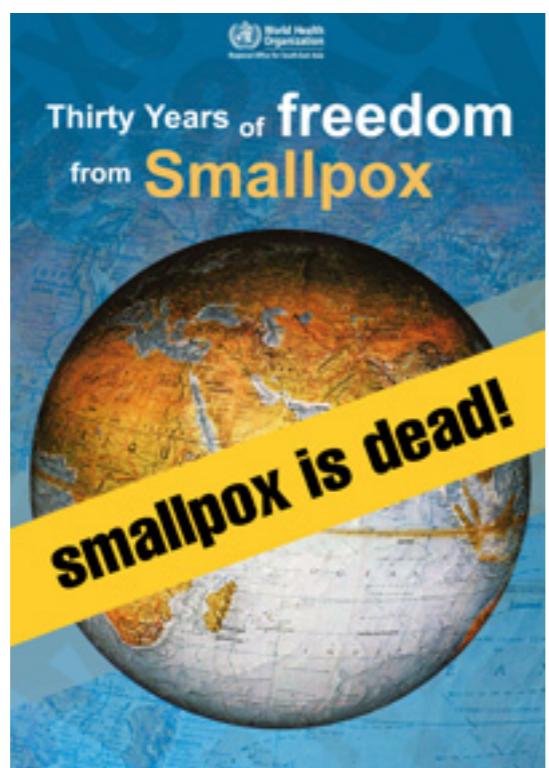
Vaccine policies: a success story



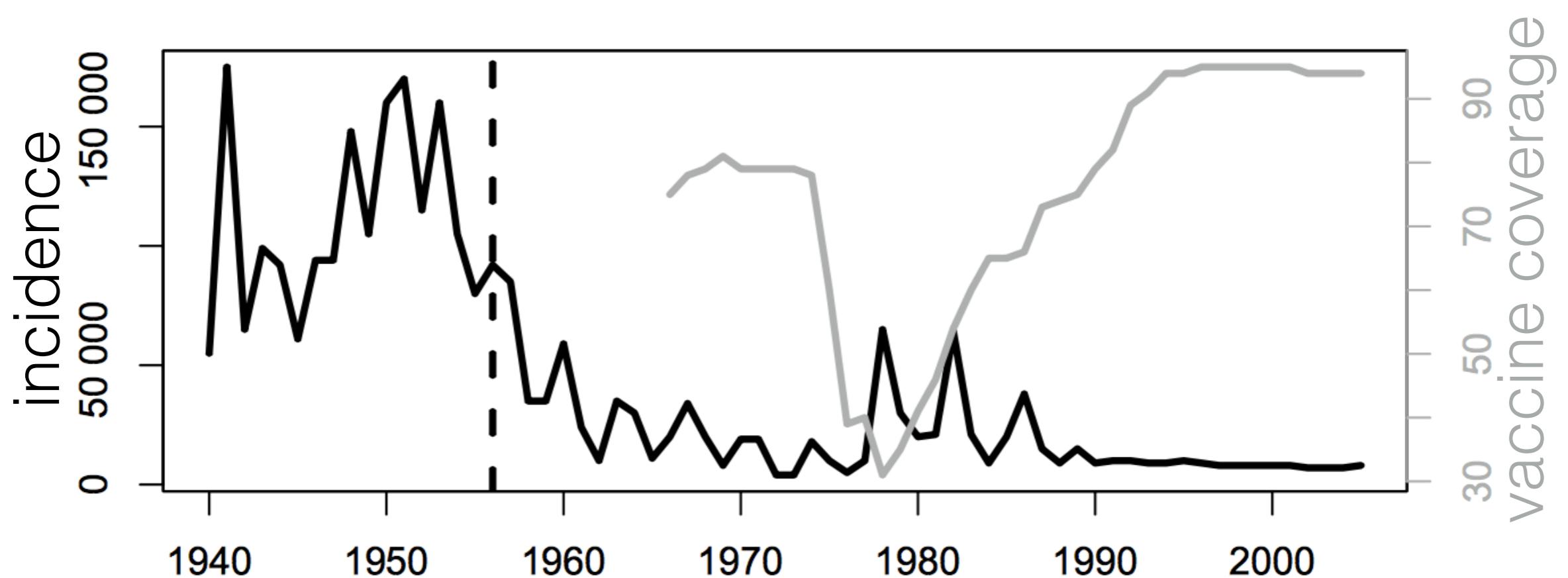
Vaccine policies: a success story



Vaccine policies: a success story



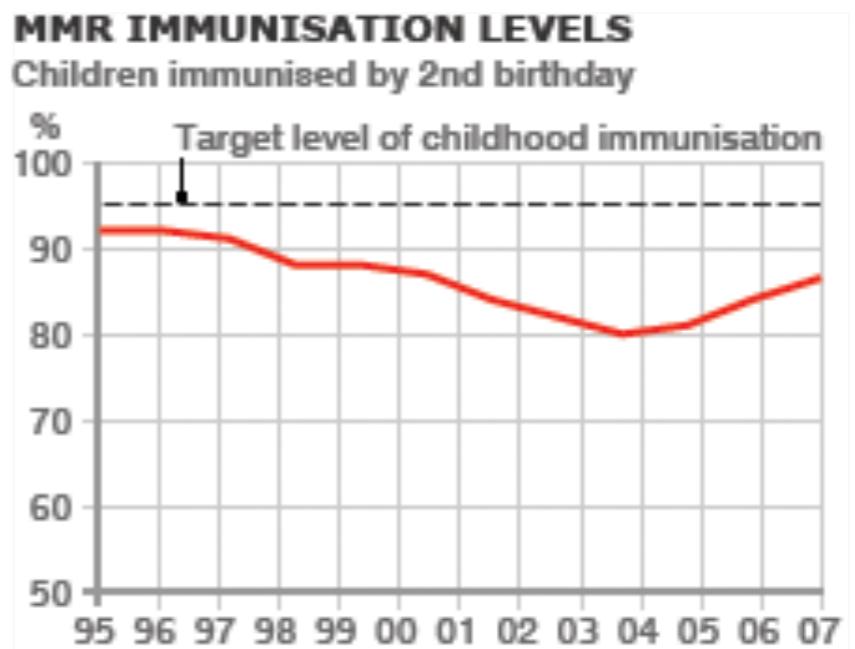
But...



But...

THE LANCET

The Lancet, Volume 351, Issue 9103, Pages 637 - 641, 28 February 1998
doi:10.1016/S0140-6736(97)11096-0



This article was retracted

RETRACTED: Ileal-lymphoid-nodular hyperplasia, non-specific colitis, and pervasive developmental disorder in children

Dr AJ Wakefield FRCS ^a , SH Murch MB ^b, A Anthony MB ^a, J Linnell PhD ^a, DM Casson MRCP ^b, M Malik MRCP ^b, M Berelowitz FRCPsych ^c, AP Dhillon MRCPPath ^a, MA Thomson FRCP ^b, P Harvey FRCP ^d, A Valentine FRCR ^e, SE Davies MRCPPath ^a, JA Walker-Smith FRCP ^a

Summary

Background

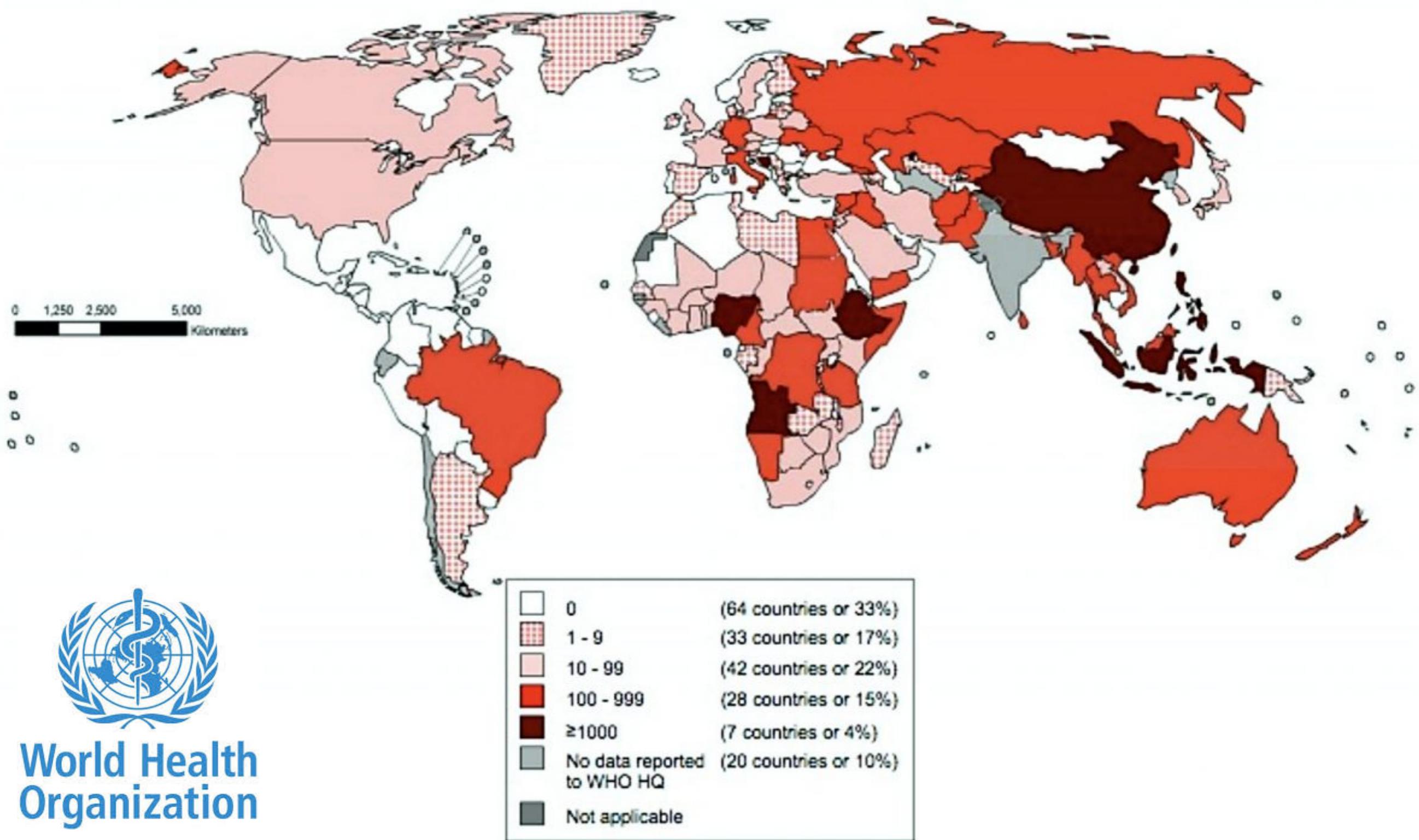
We investigated a consecutive series of children with chronic enterocolitis and regressive developmental disorder.

Methods

12 children (mean age 6 years [range 3–10], 11 boys) were referred to a paediatric gastroenterology unit with a history of normal development followed by loss of acquired skills, including language, together with diarrhoea and abdominal pain. Children underwent gastroenterological, neurological, and developmental assessment and review of developmental records. Ileocolonoscopy and biopsy sampling, magnetic-resonance imaging (MRI), electroencephalography (EEG), and lumbar puncture were done under sedation. Barium follow-through radiography was done where possible. Biochemical, haematological, and immunological profiles were examined.

RETRACTED

But...

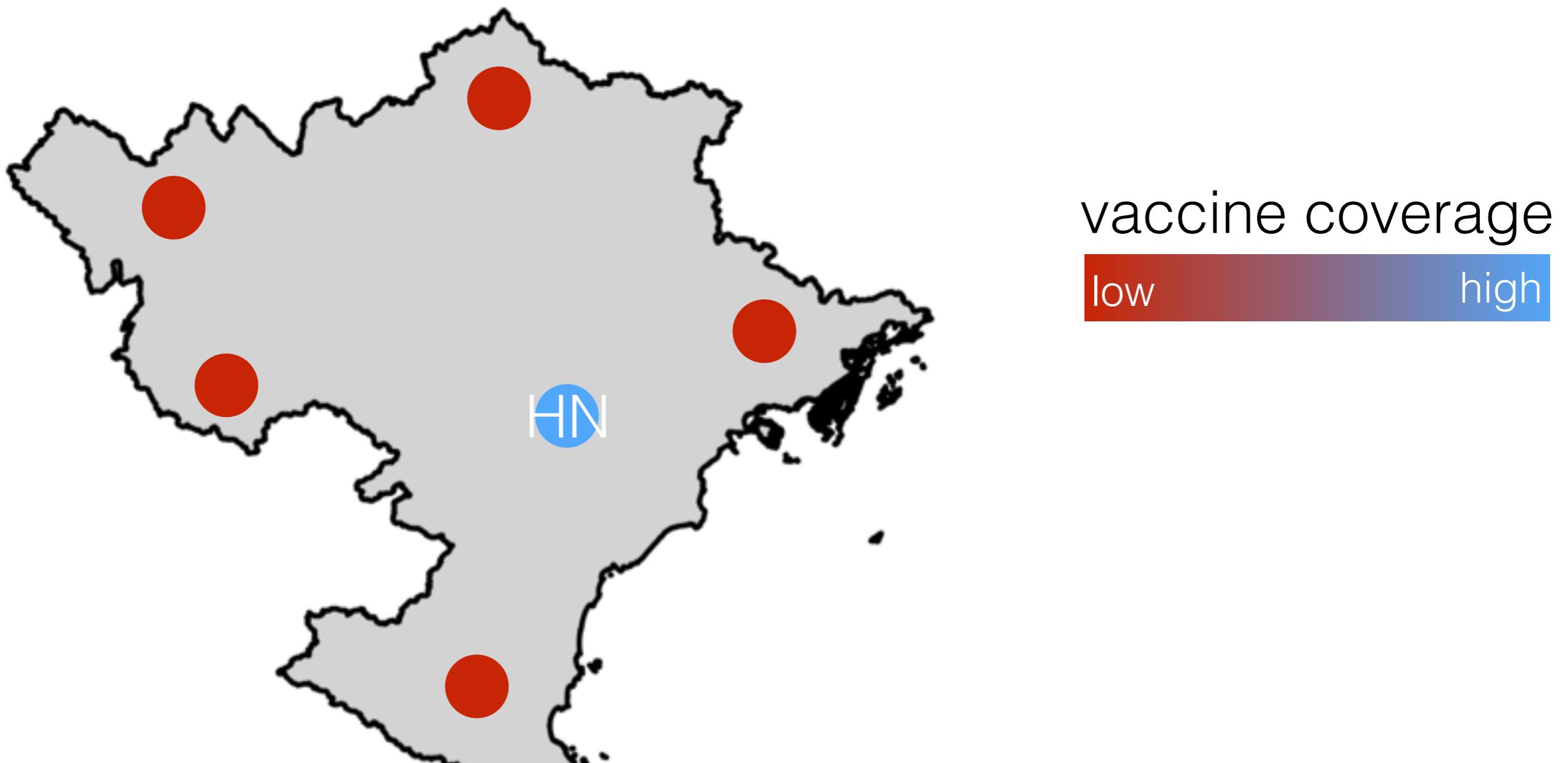


Consequences of vaccination

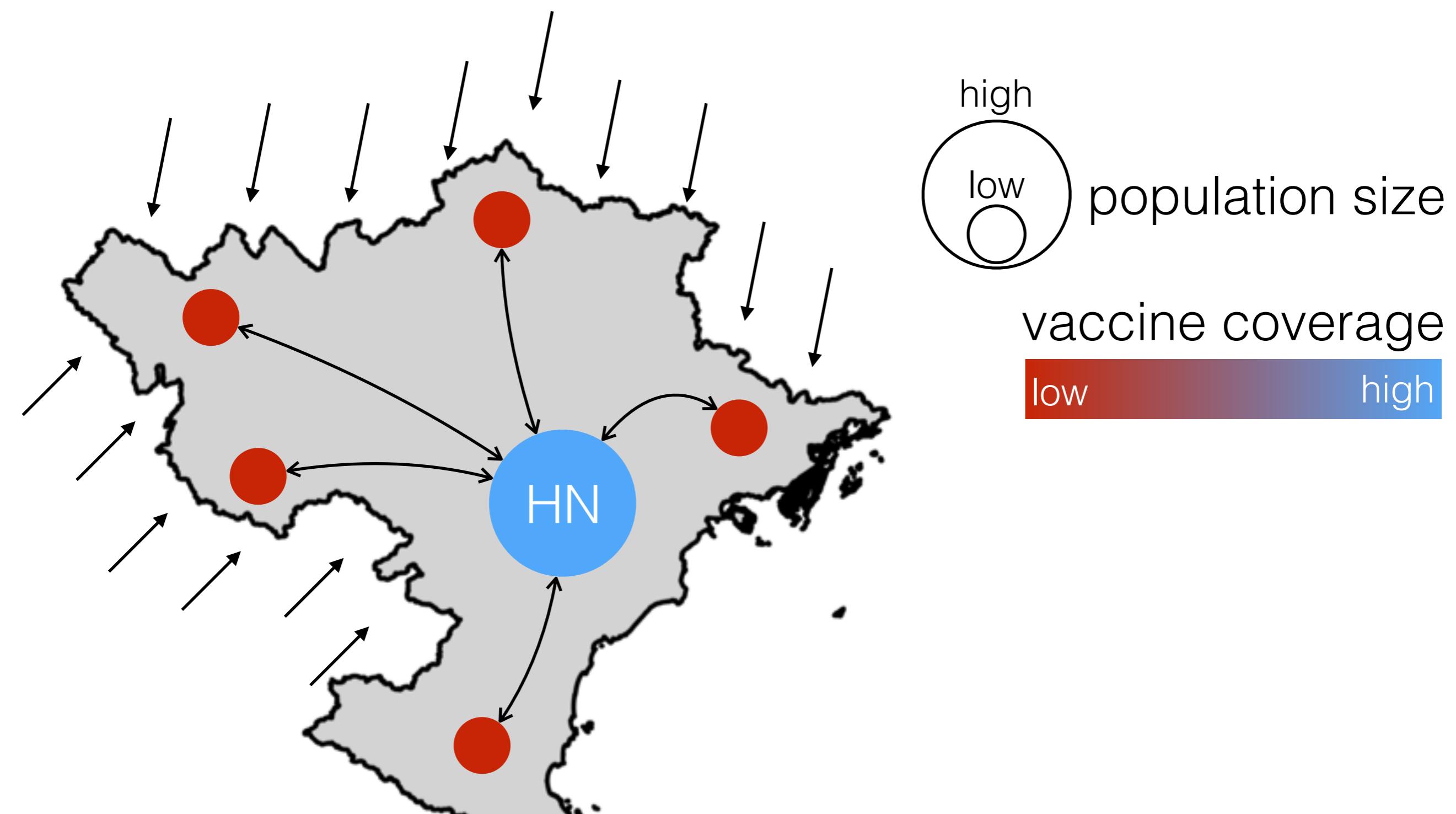
Consequences of vaccination

- decreases incidence
- increases age at infection
- may alter severity
- alters periodicity
- decreases spatial synchrony
- decreases maternal protection
- may increase virulence
- etc...

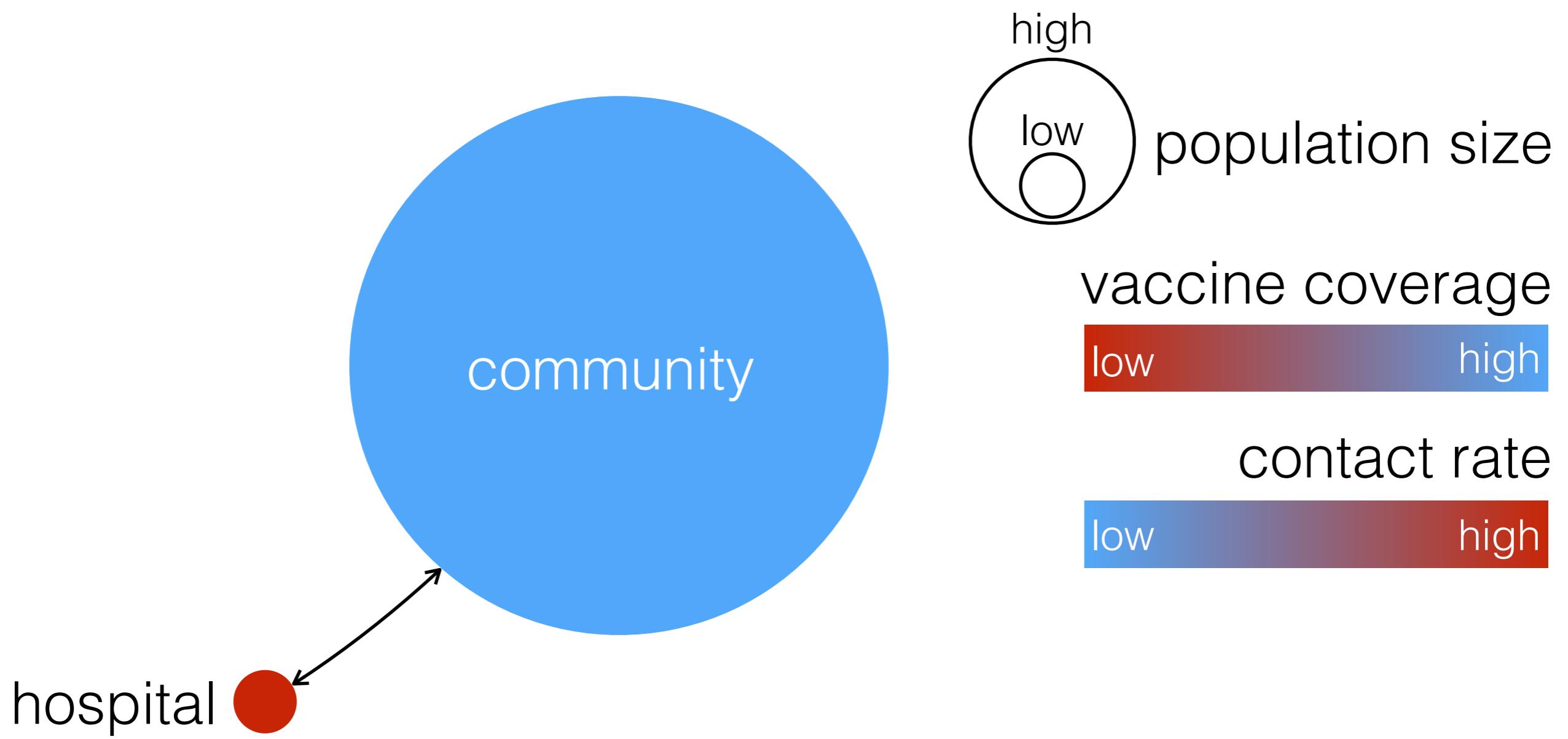
Measles in northern Vietnam



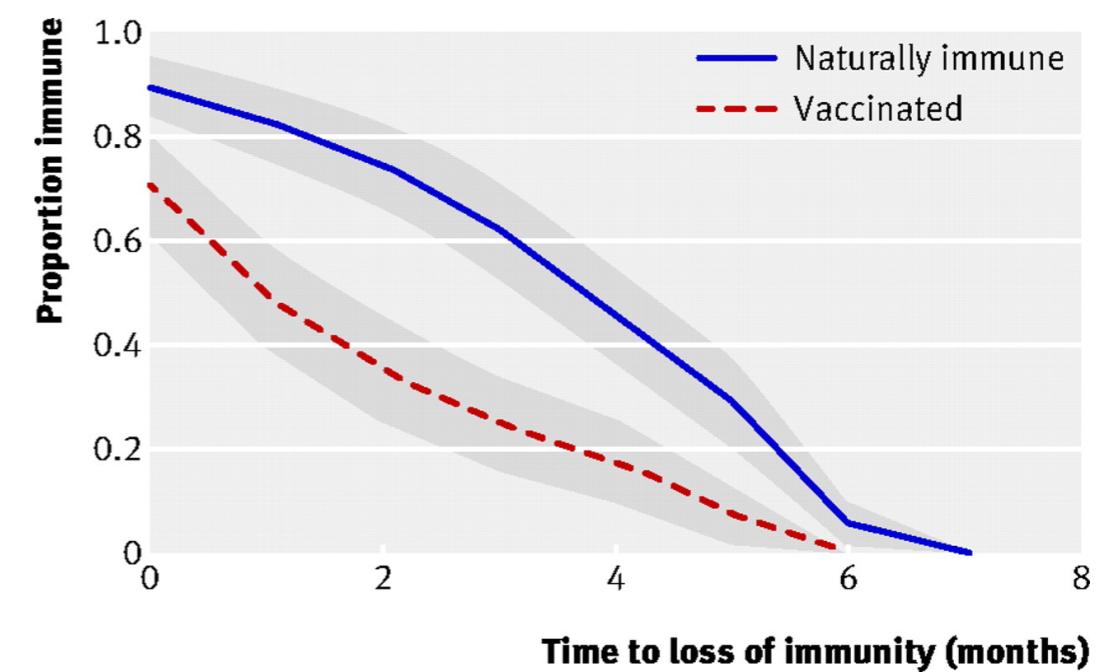
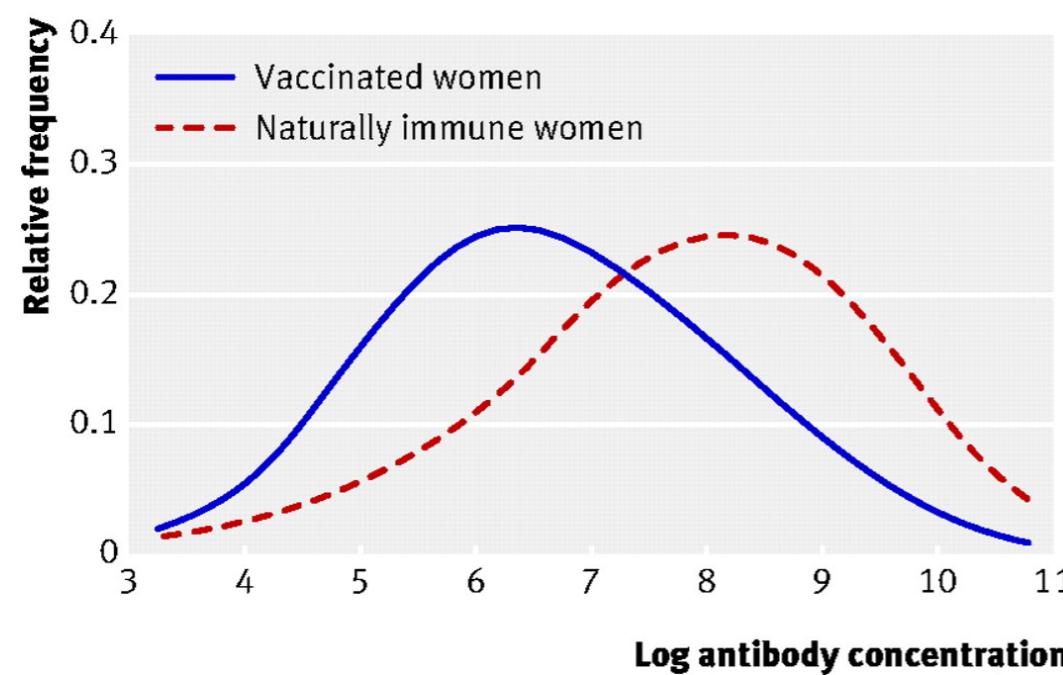
Measles in northern Vietnam

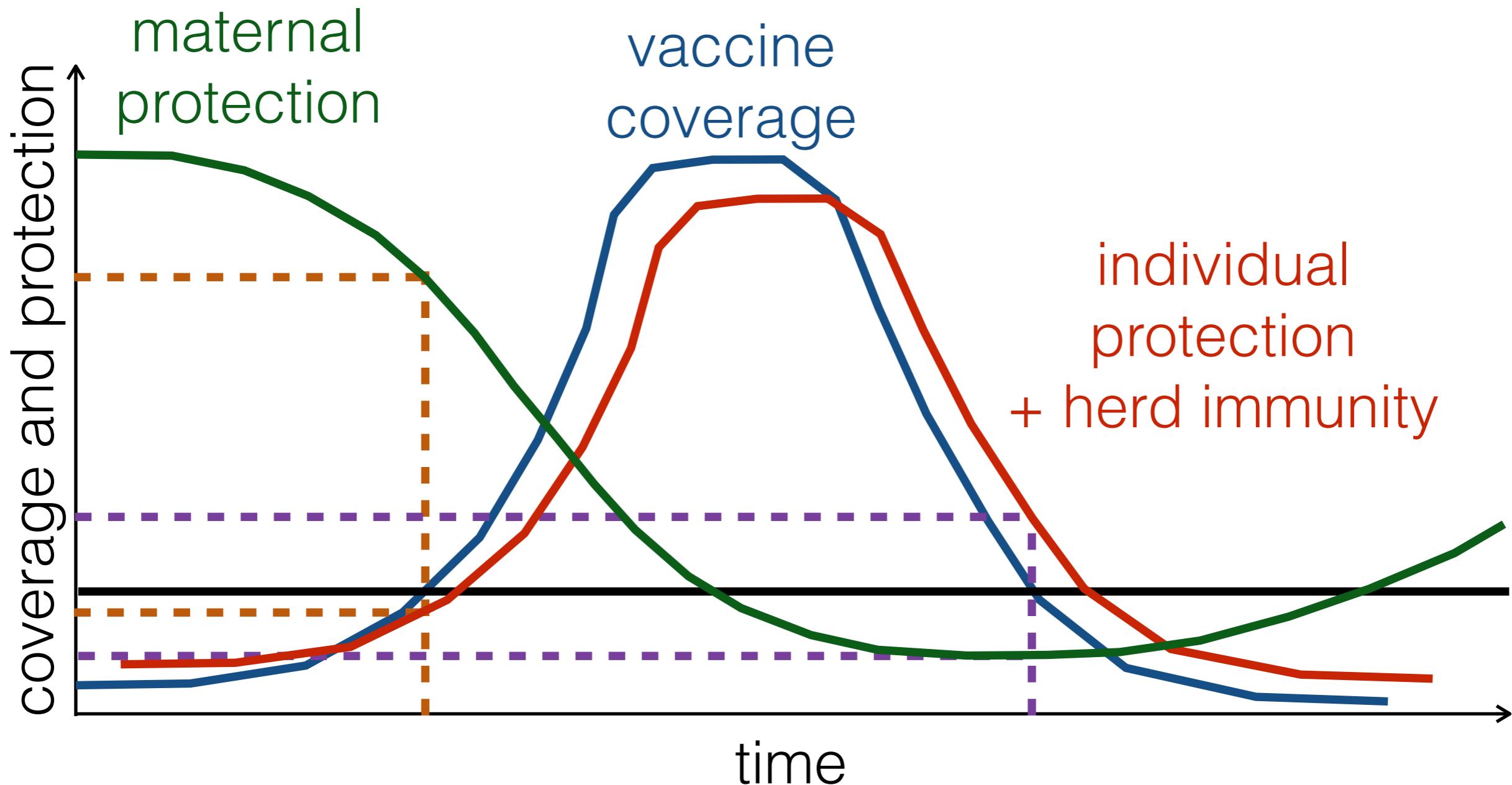


Measles in northern Vietnam



Maternal protection





Conclusions

Conclusions

Disease eradication is difficult

Many constraints to weight

Complex dynamics with emerging properties and interactions

Many consequences of vaccination

Models help understanding and decision making

Models help understanding and decision making

(sero-)surveillance data

Thank you