Infectious diseases: time, space and control

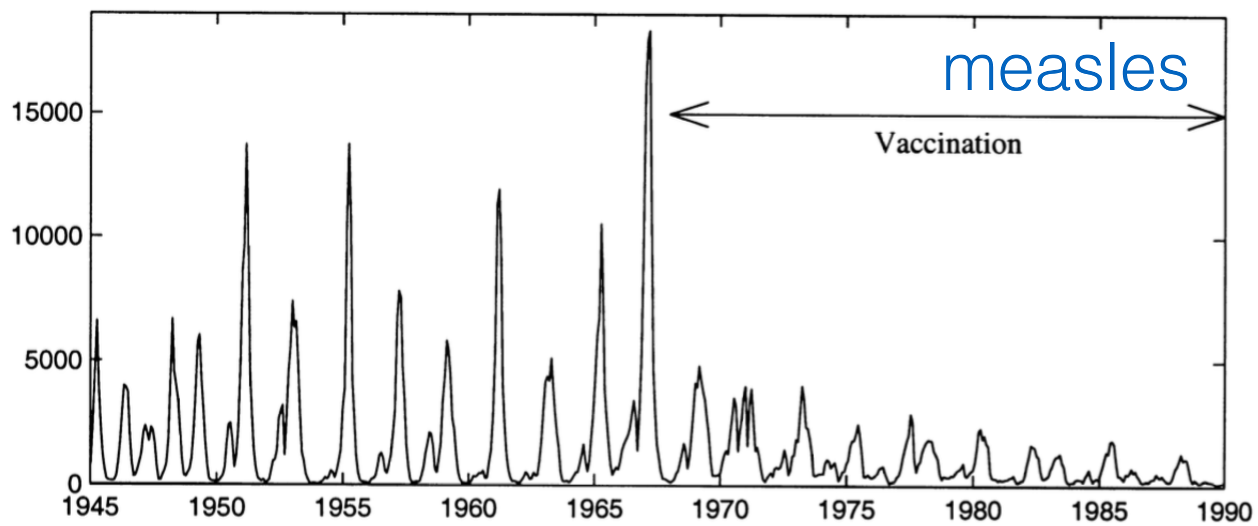
Marc Choisy

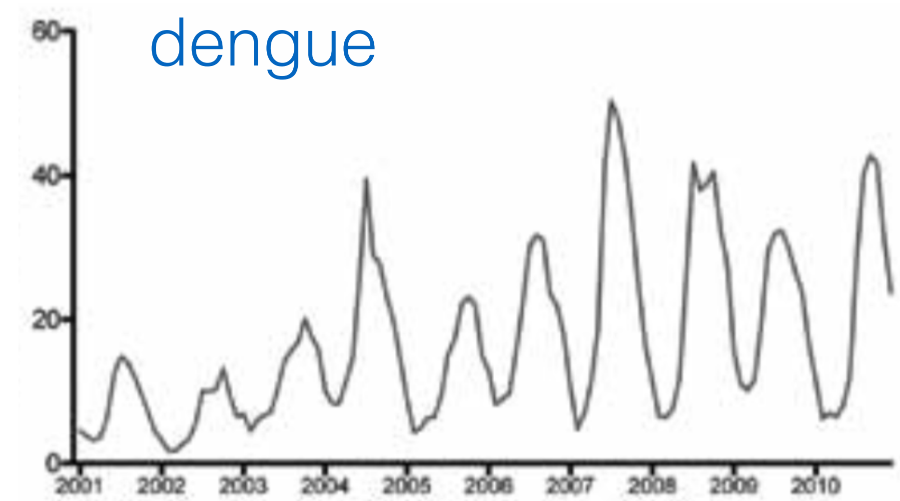
Seasonality

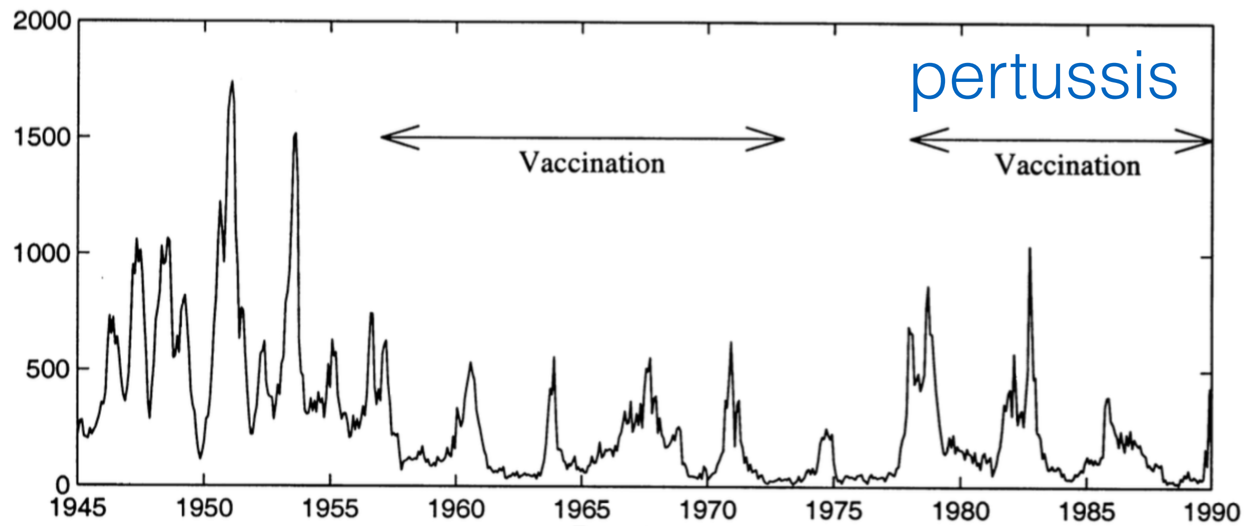
Spatial dynamics

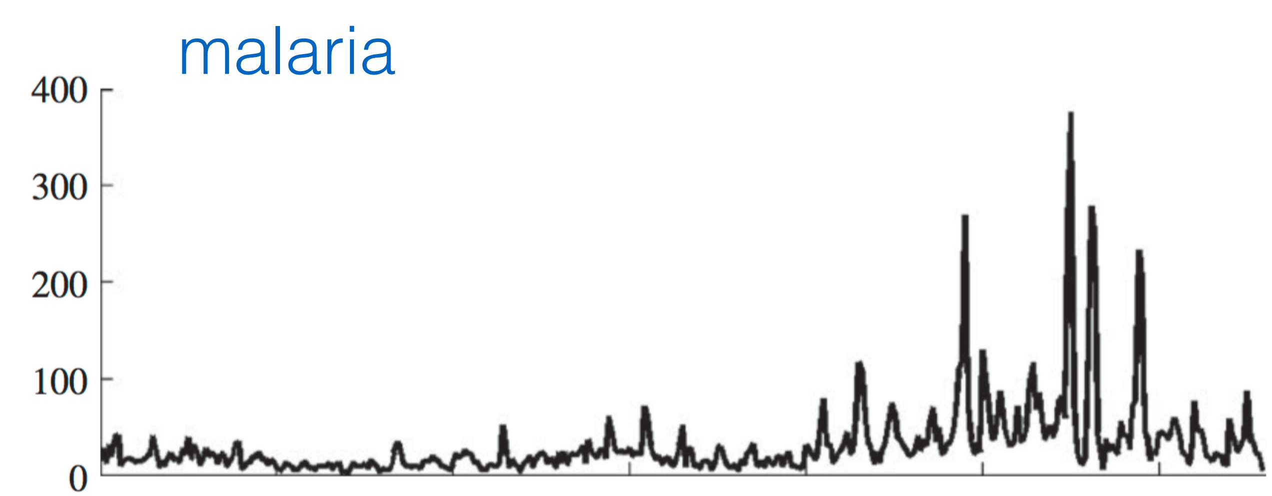
Optimal control

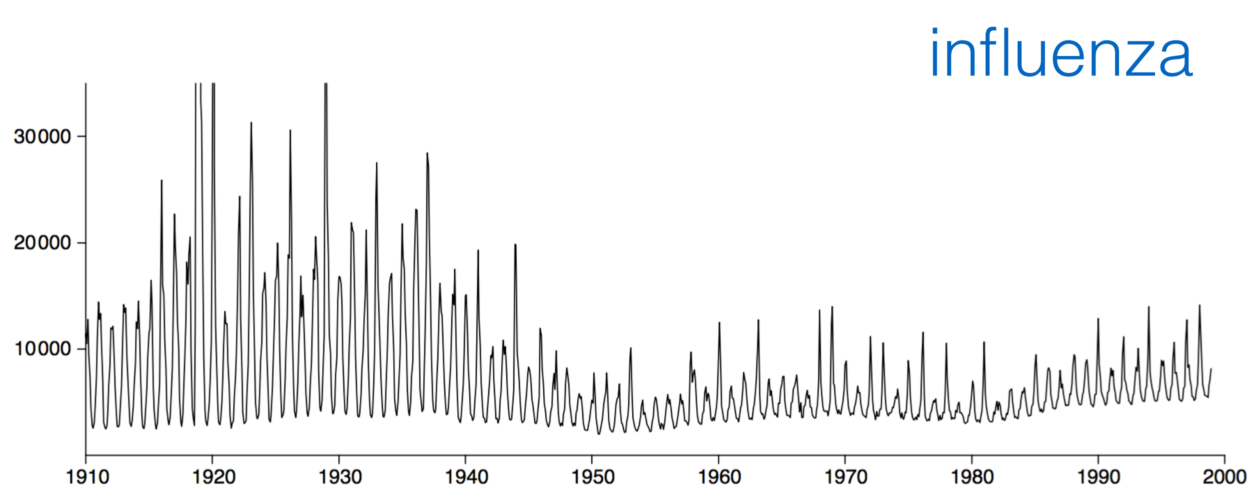
Seasonality of infectious diseases

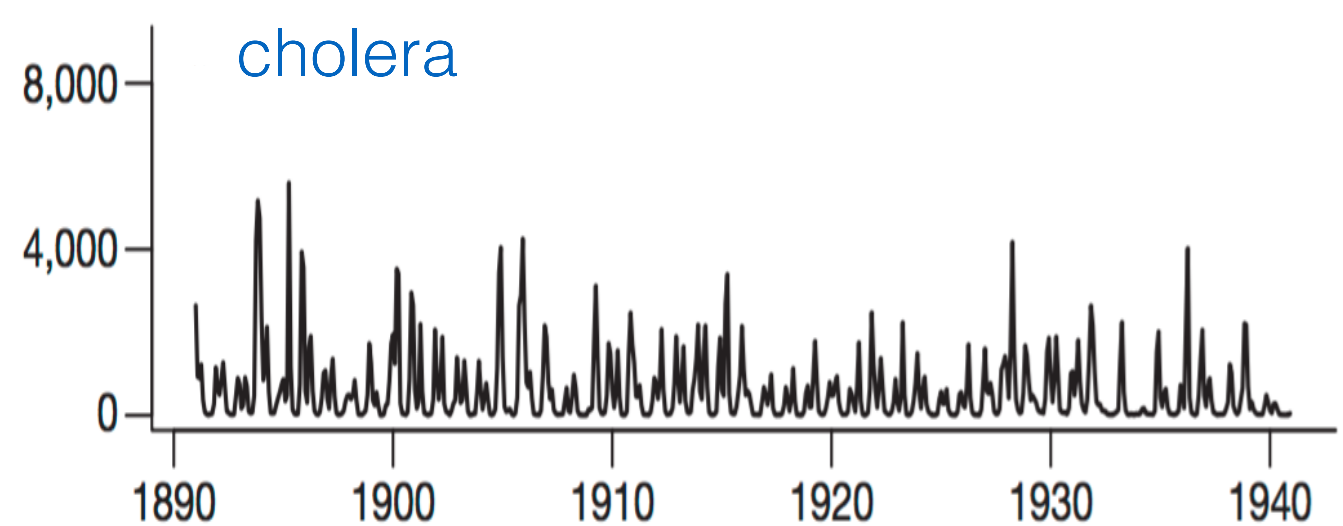




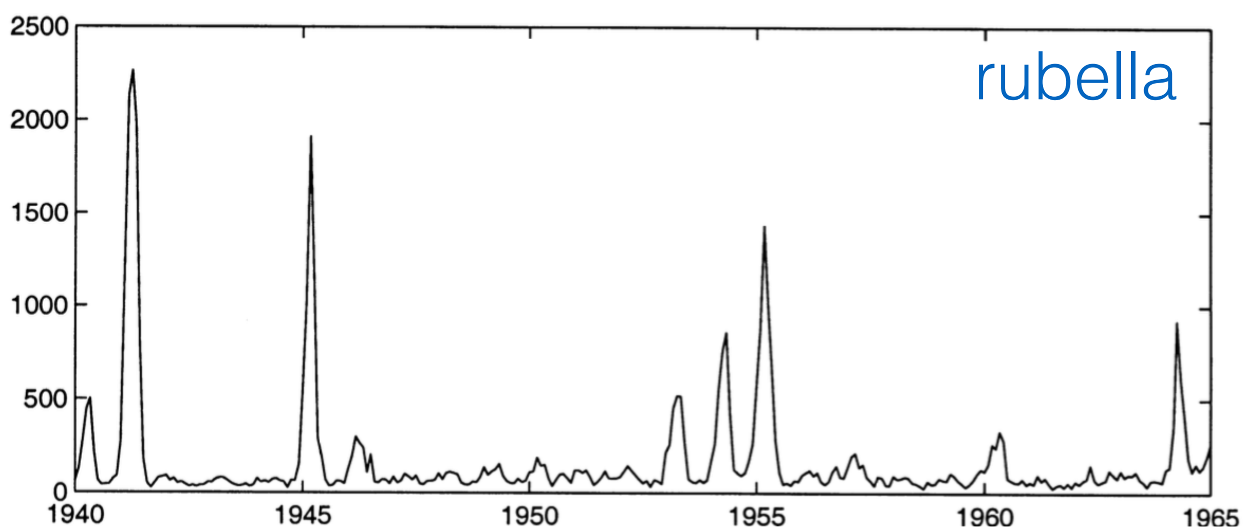


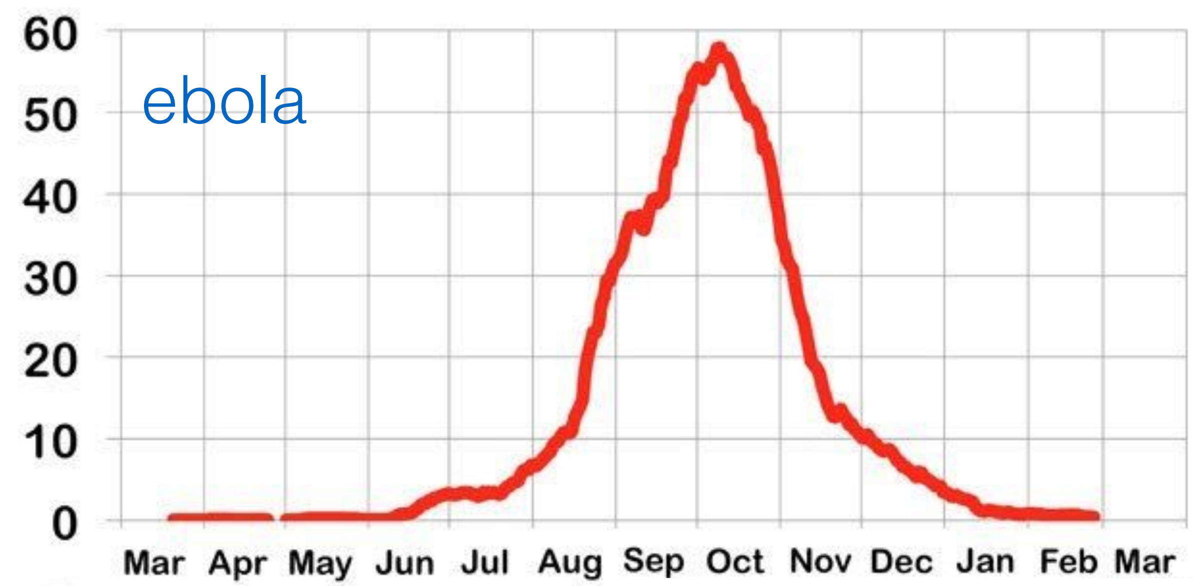


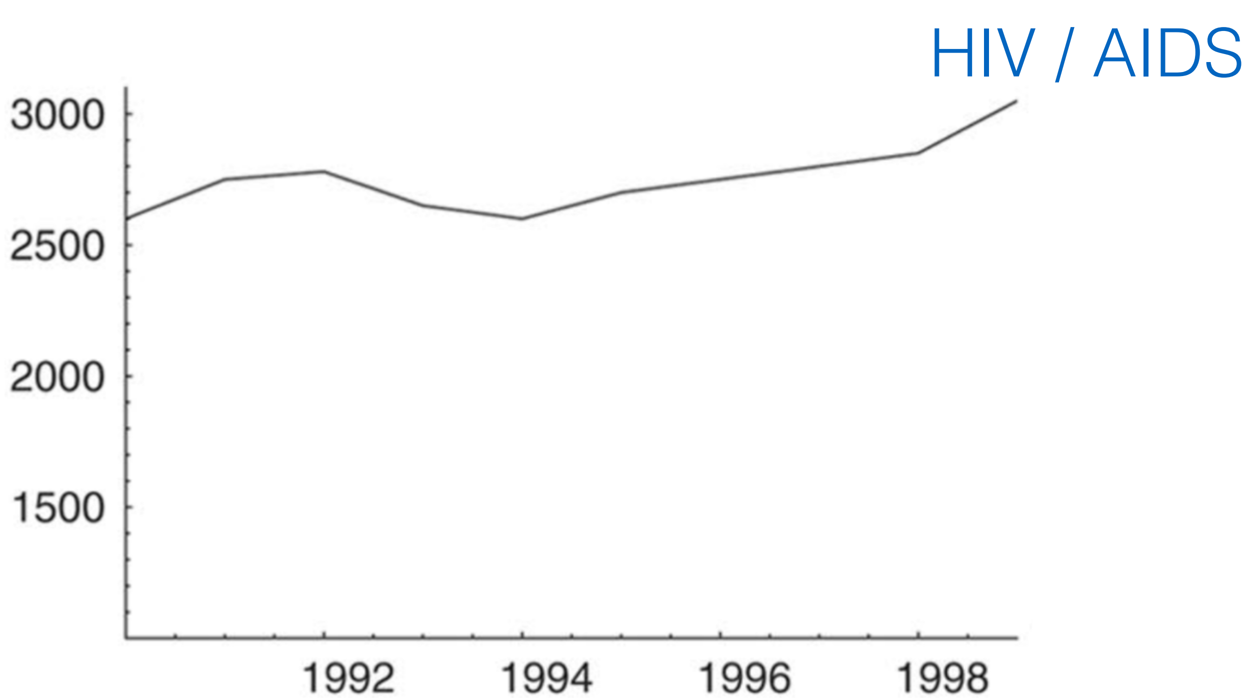




Seasonality of infectious diseases







Seasonality of infectious diseases

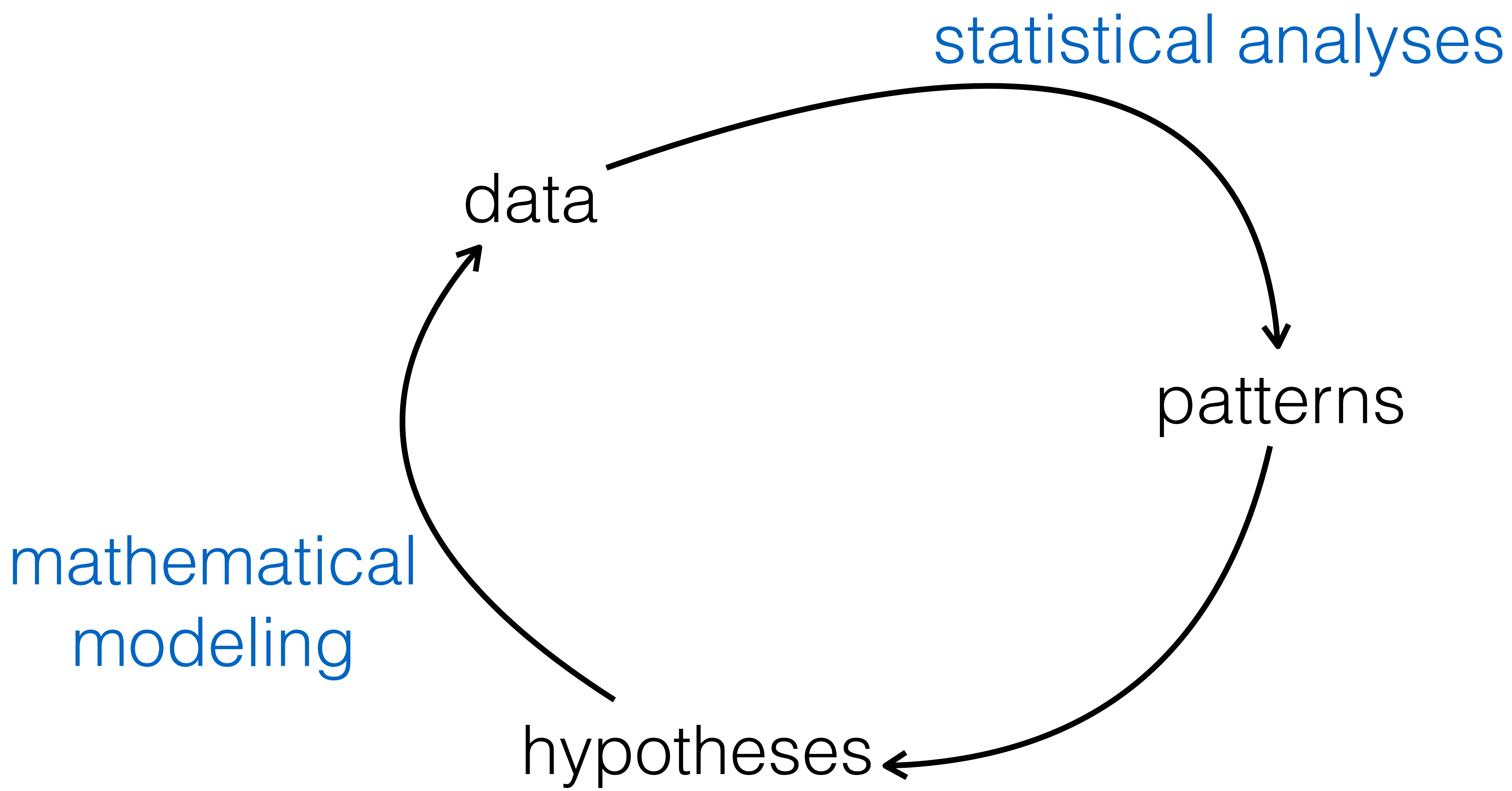
Why studying seasonality?

- can help forecasting
- can affect persistance

How to study seasonality?

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

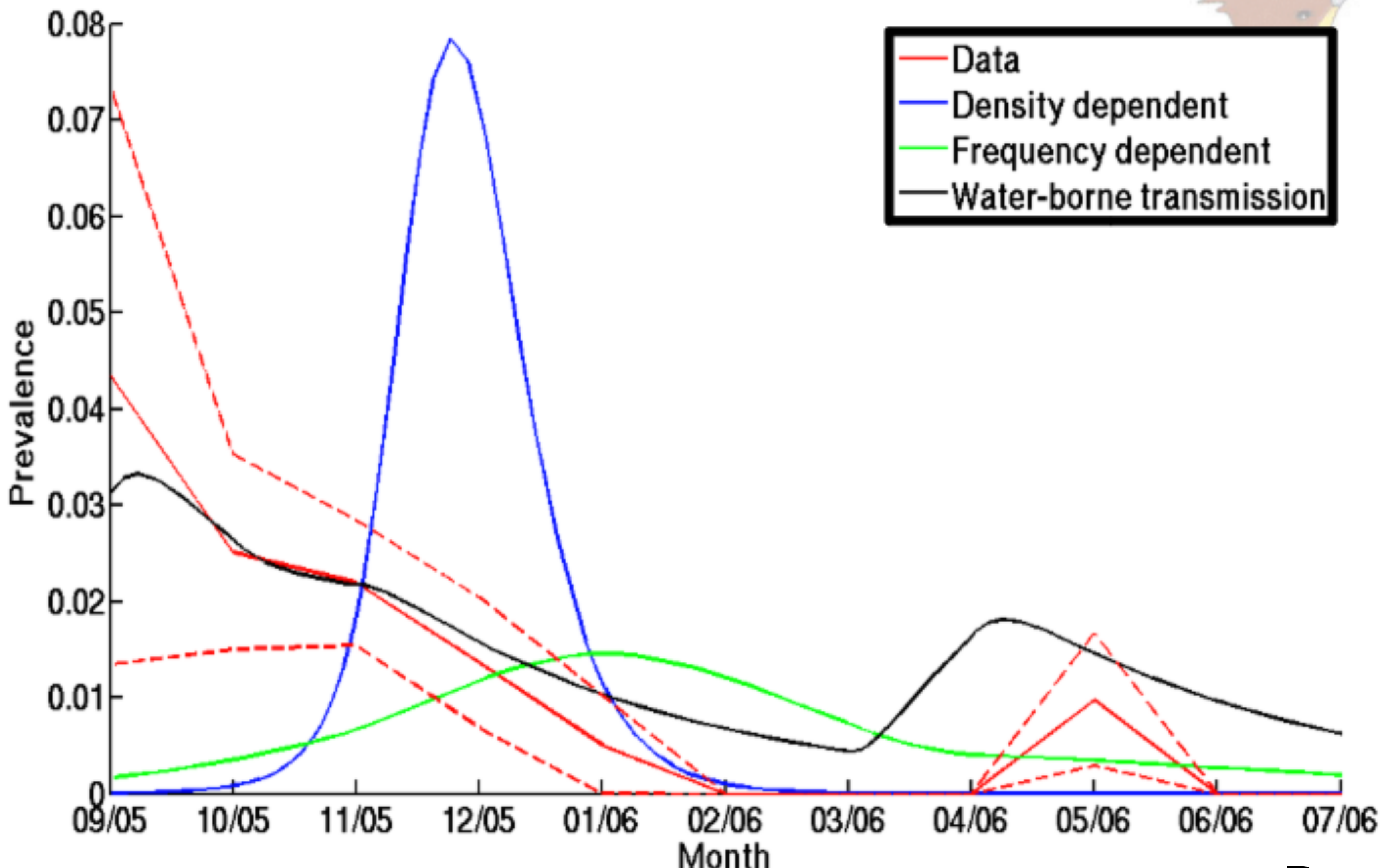
Seasonality of infectious diseases



Testing hypotheses: Competing models

	implementation		**calibration**		**selection**	
hypothesis 1	→	model 1	→	fit 1		
hypothesis 2	→	model 2	→	fit 2	→	best fit
⋮		⋮		⋮		
hypothesis n	→	model n	→	fit n		

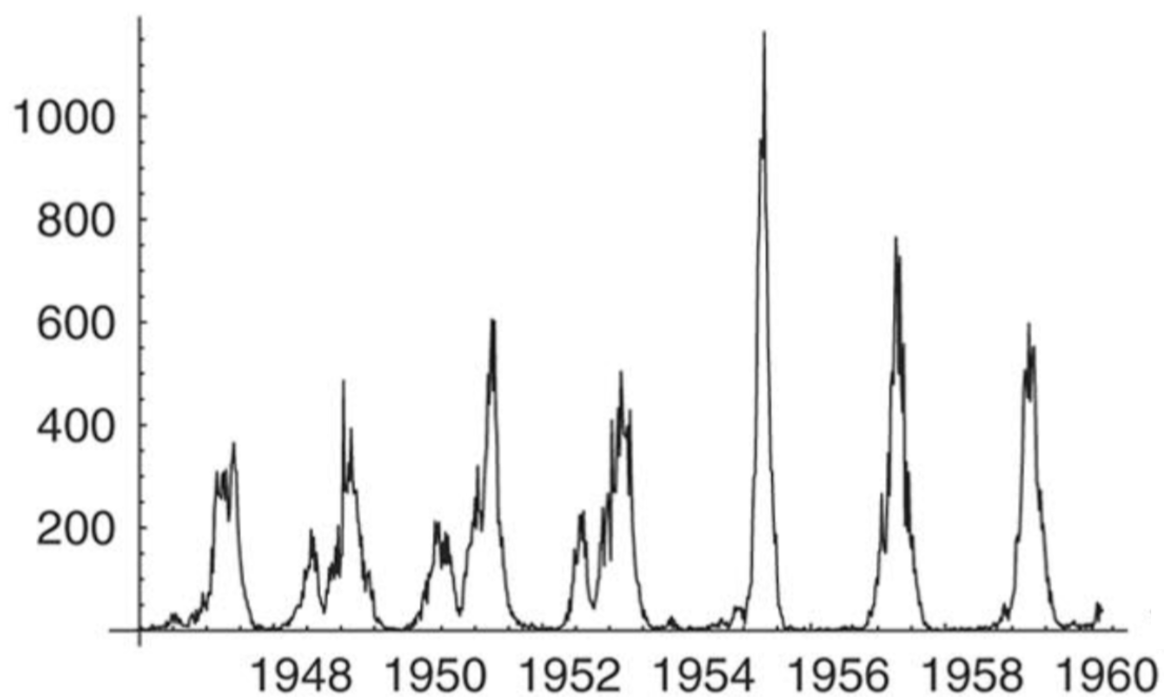
Testing hypotheses: Competing models



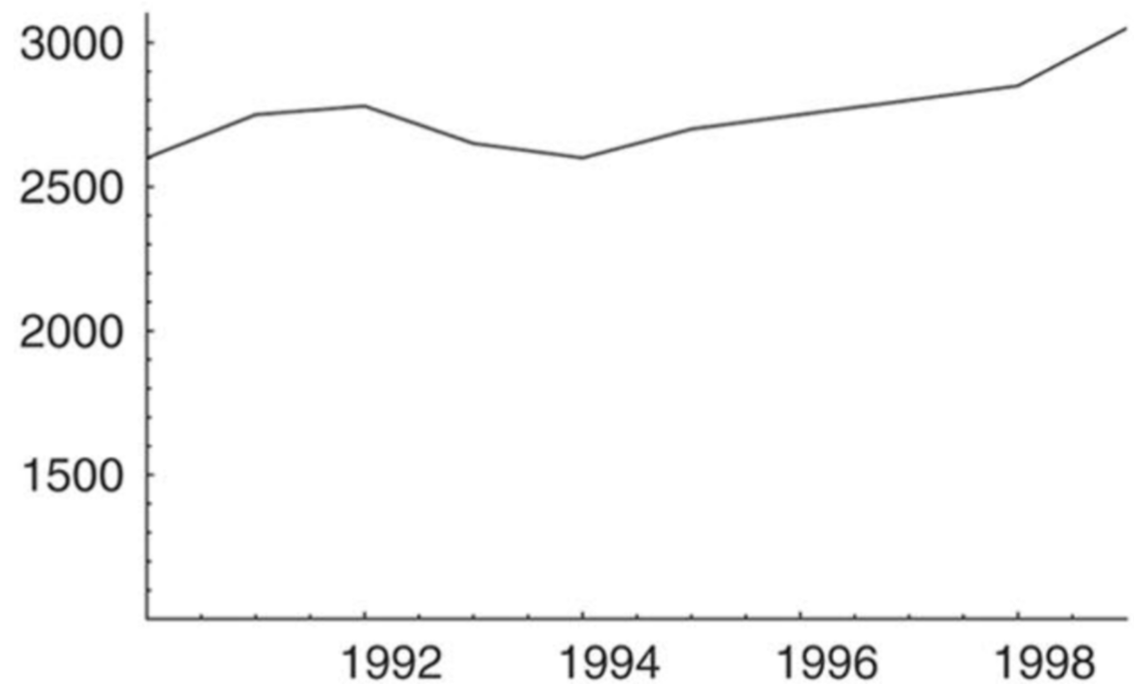
Roche et al. 2008

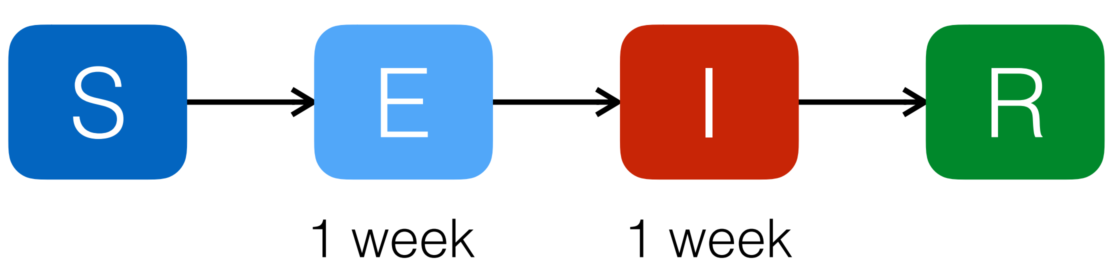
Causes of seasonality: Intrinsic epidemiological dynamics

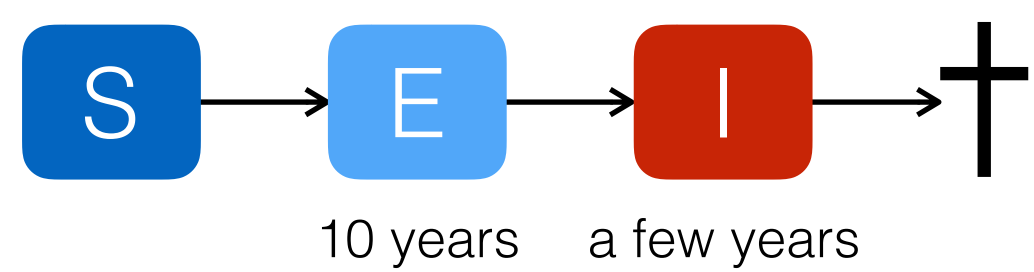
measles



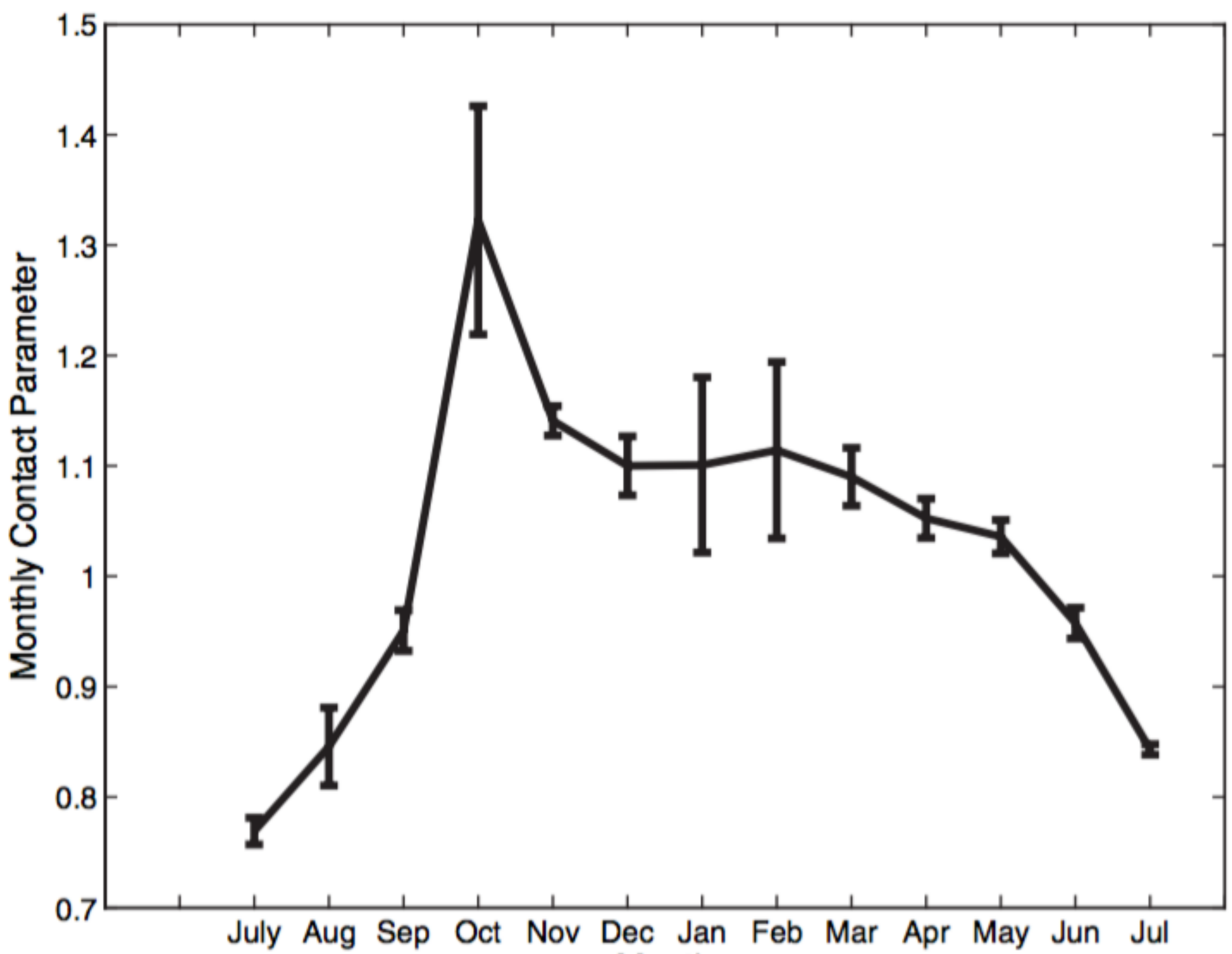
HIV / AIDS

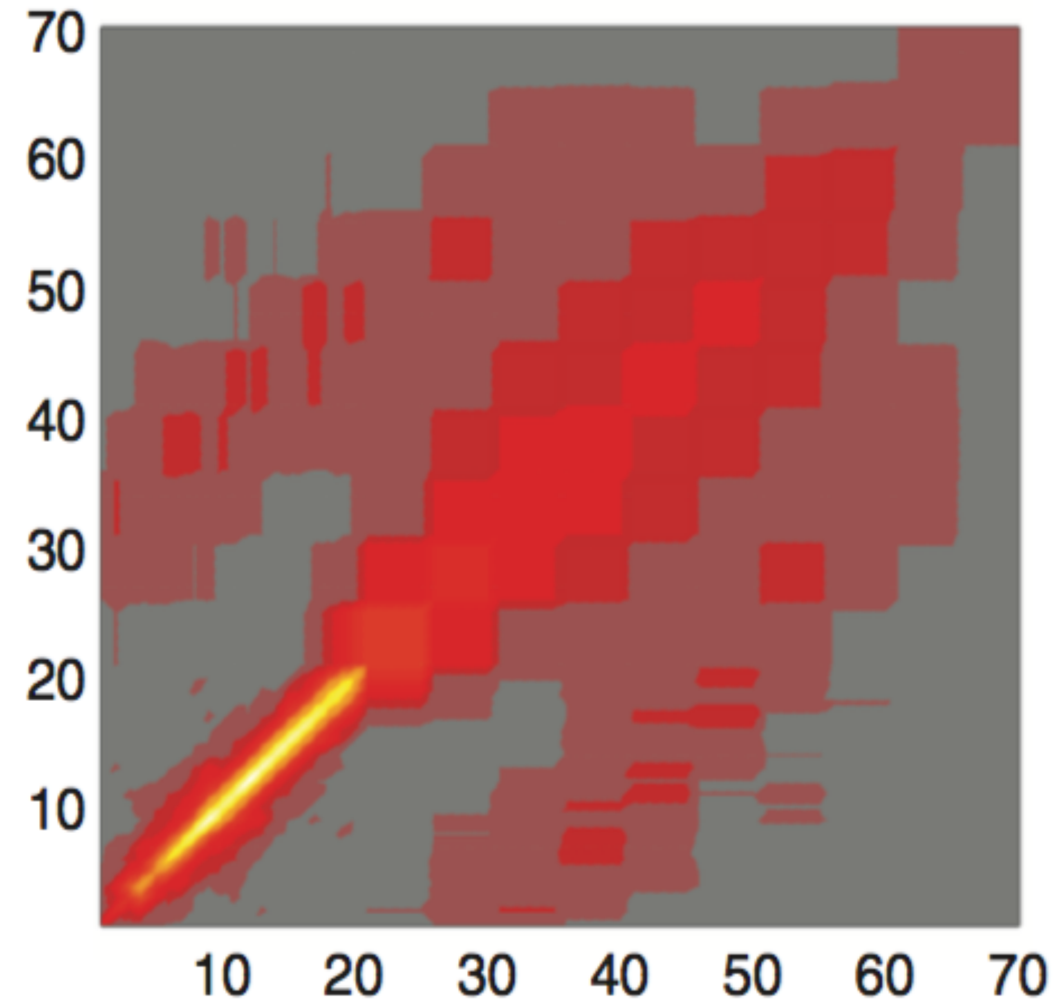






Causes of seasonality: sociology

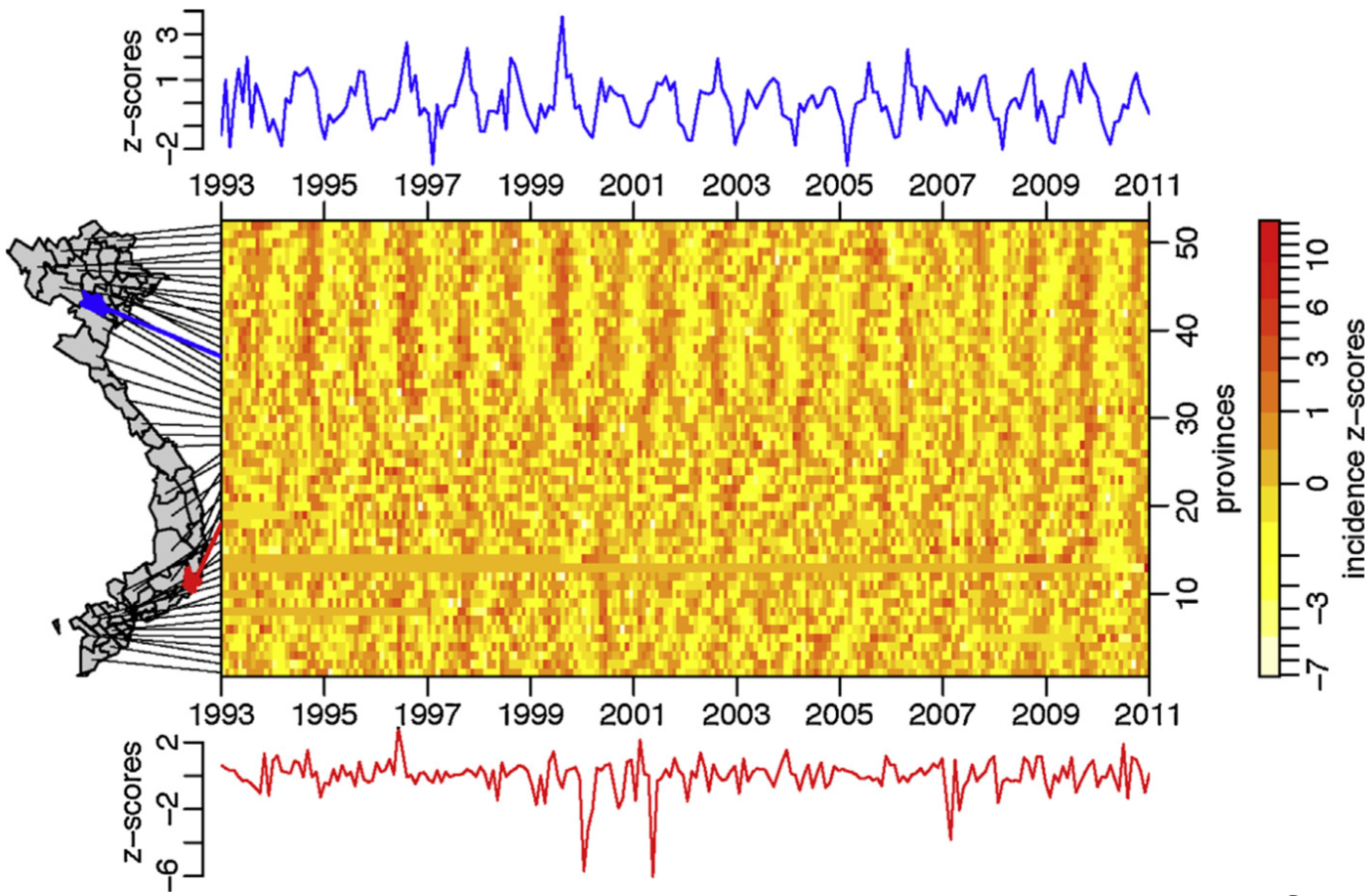


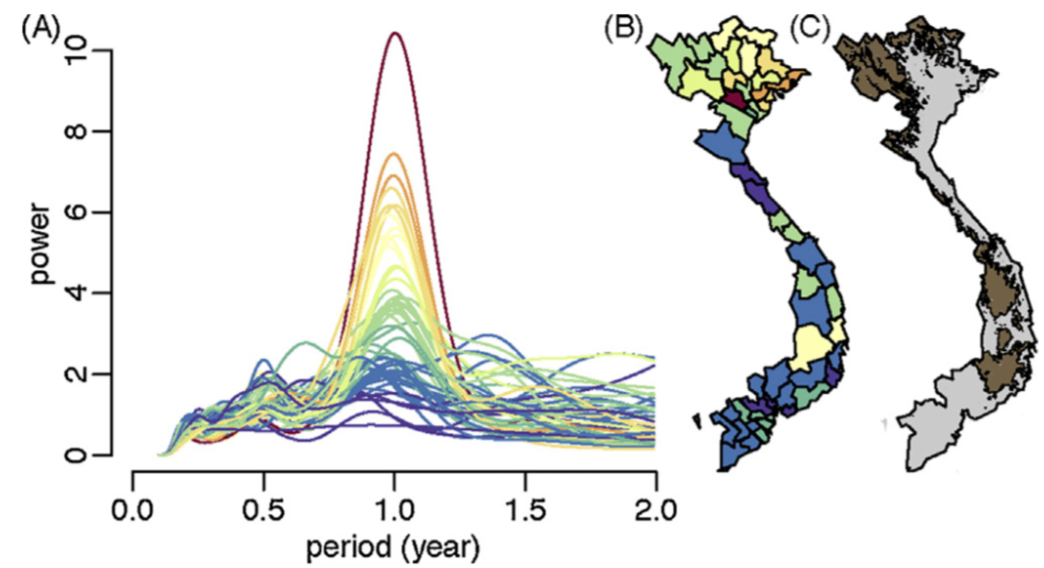


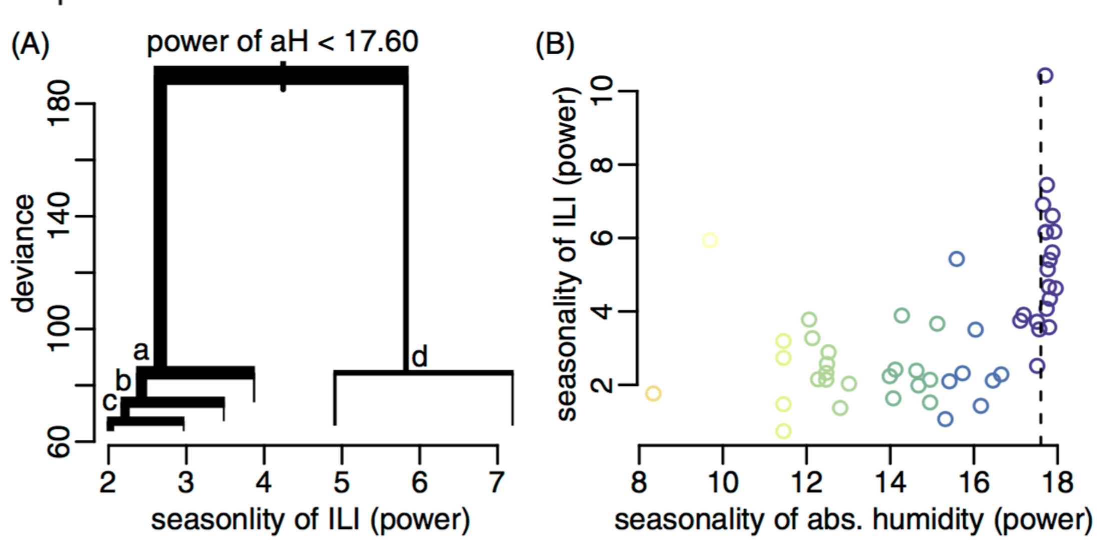
Soper 1929

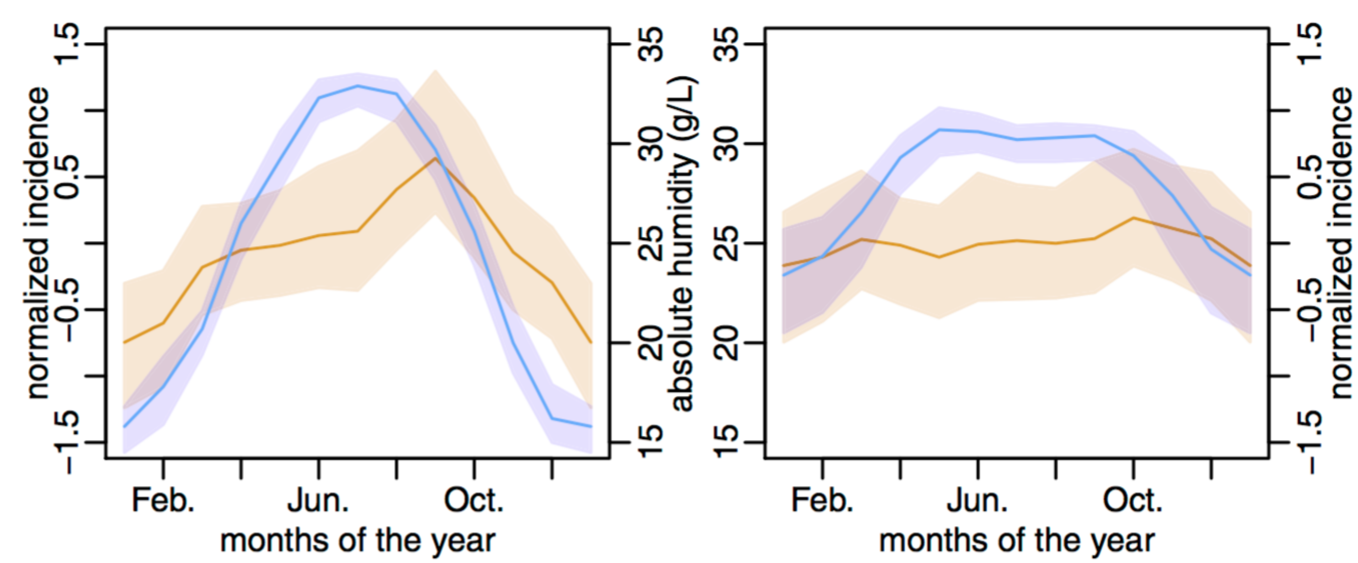
Rohani et al. 2010

Causes of seasonality: meteorology



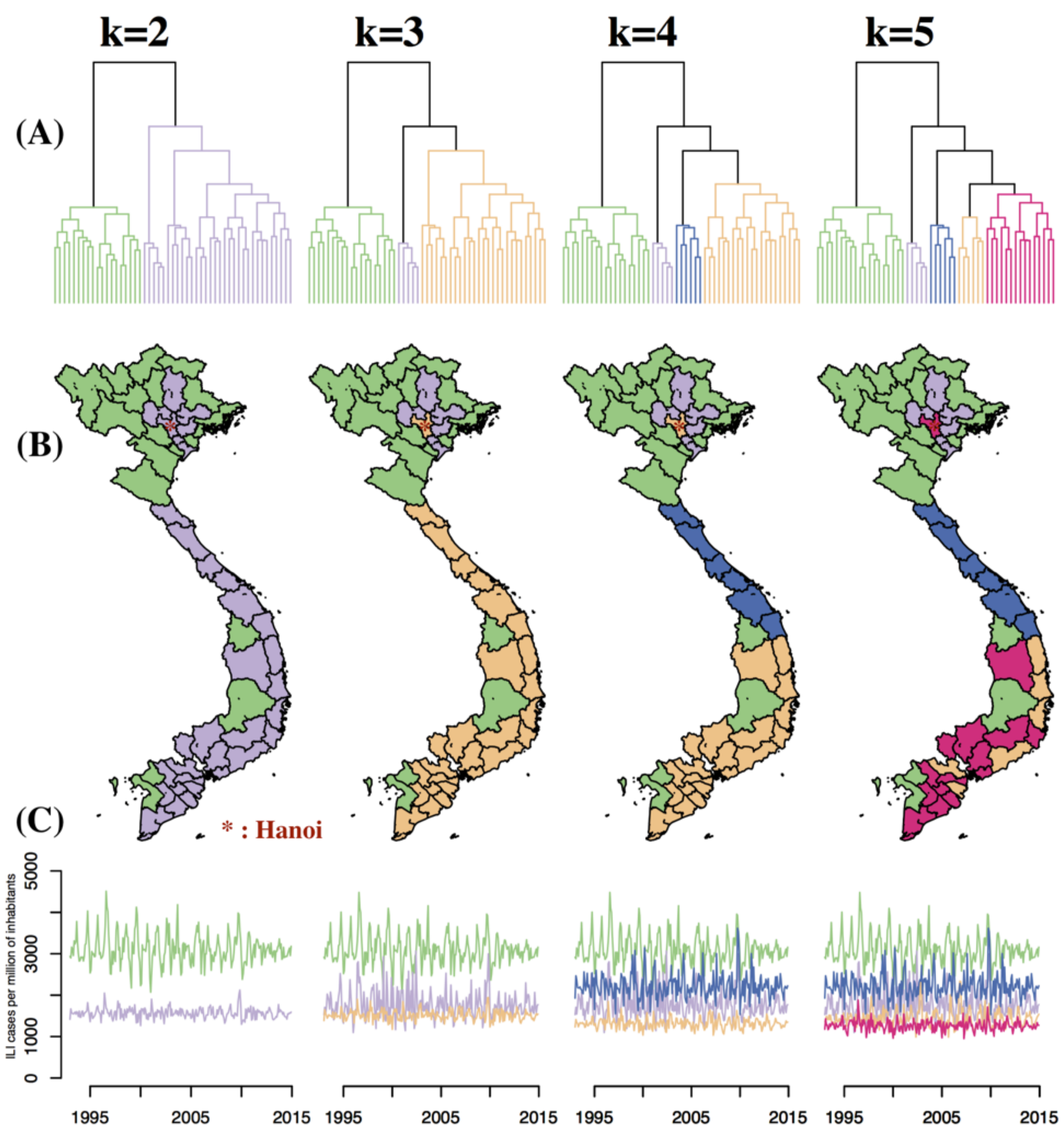


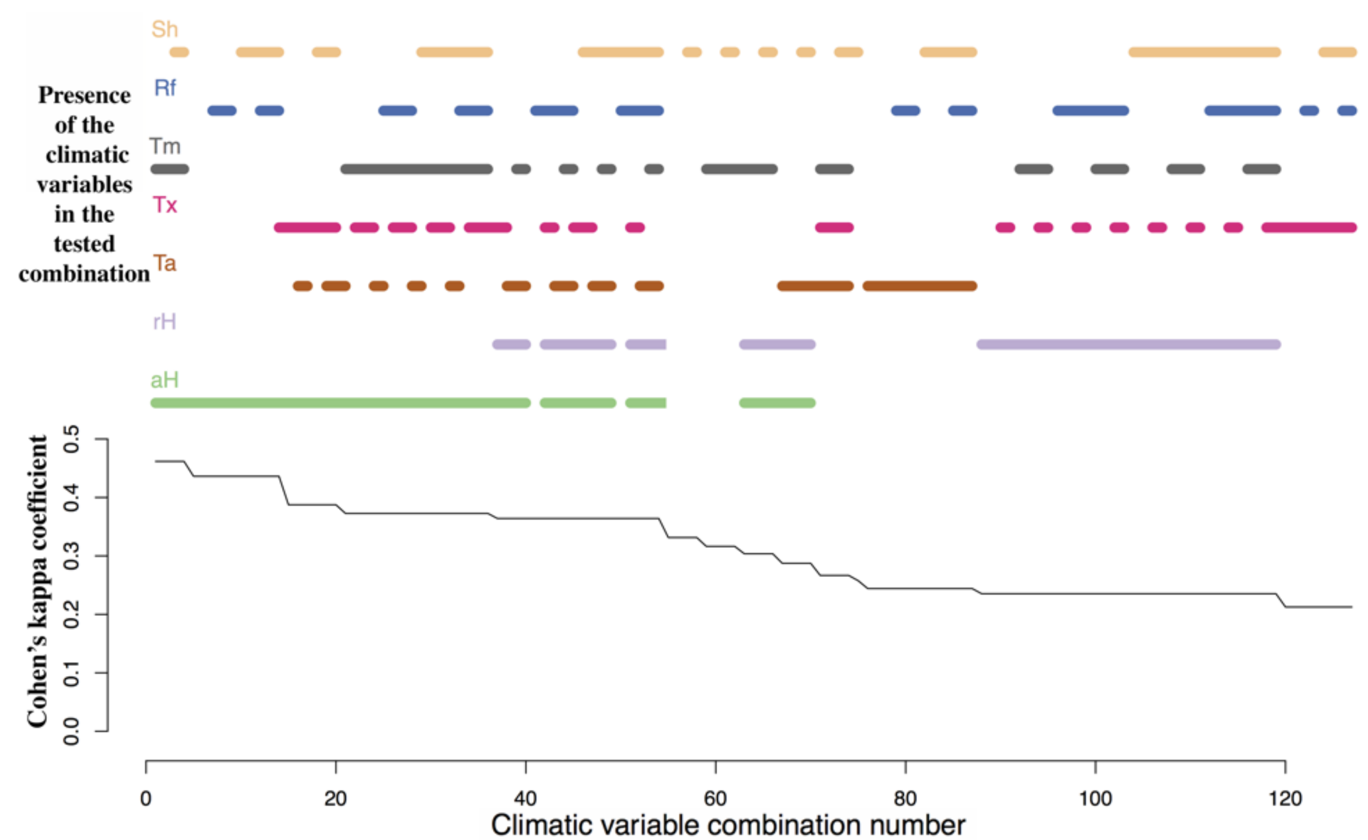




Pham et al. 2015

Causes of seasonality: meteorology





Bosshardt et al. 2016

Seasonality of infectious diseases

Why cause seasonality?

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

Seasonality of infectious diseases

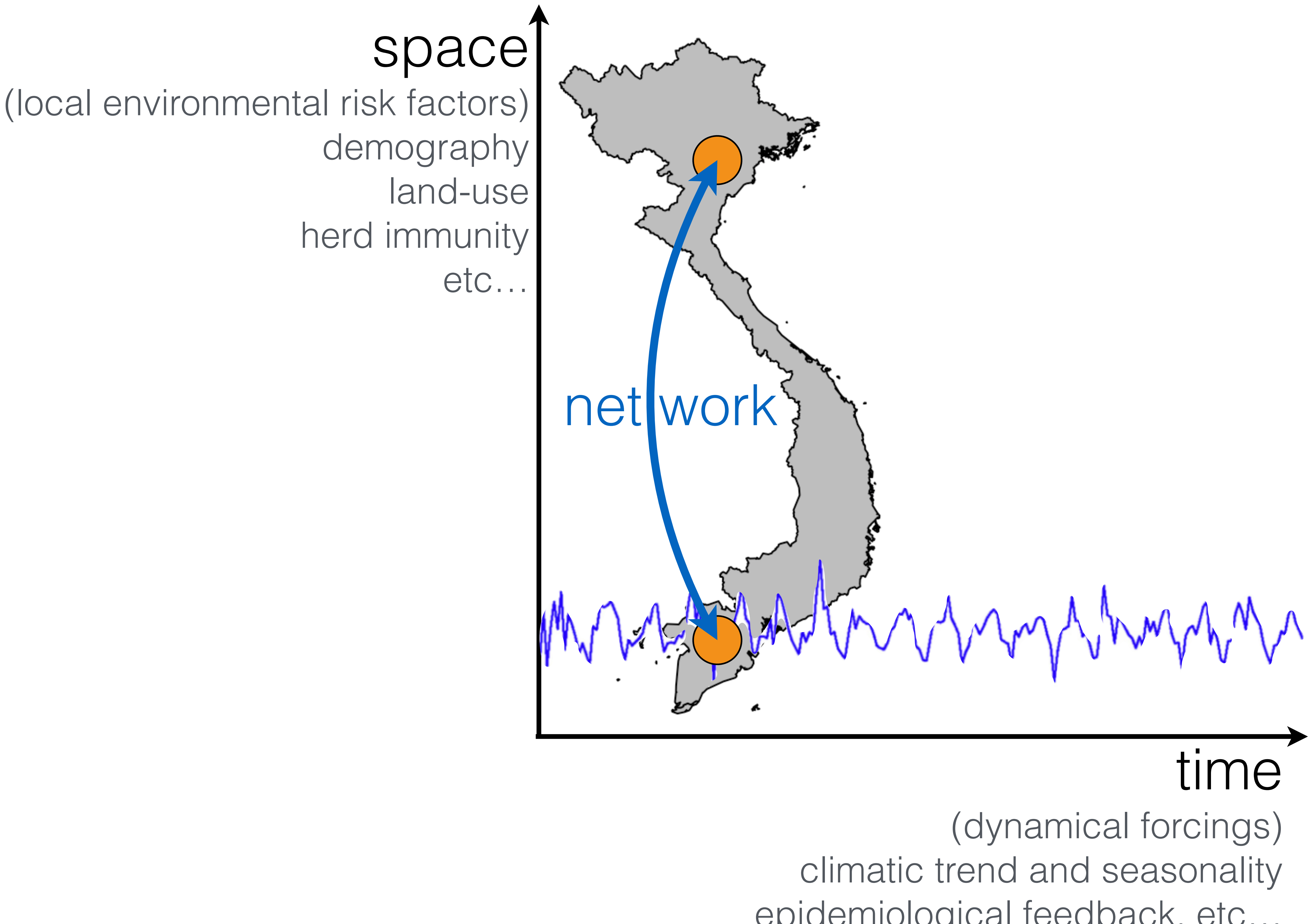
Seasonality

Spatial dynamics

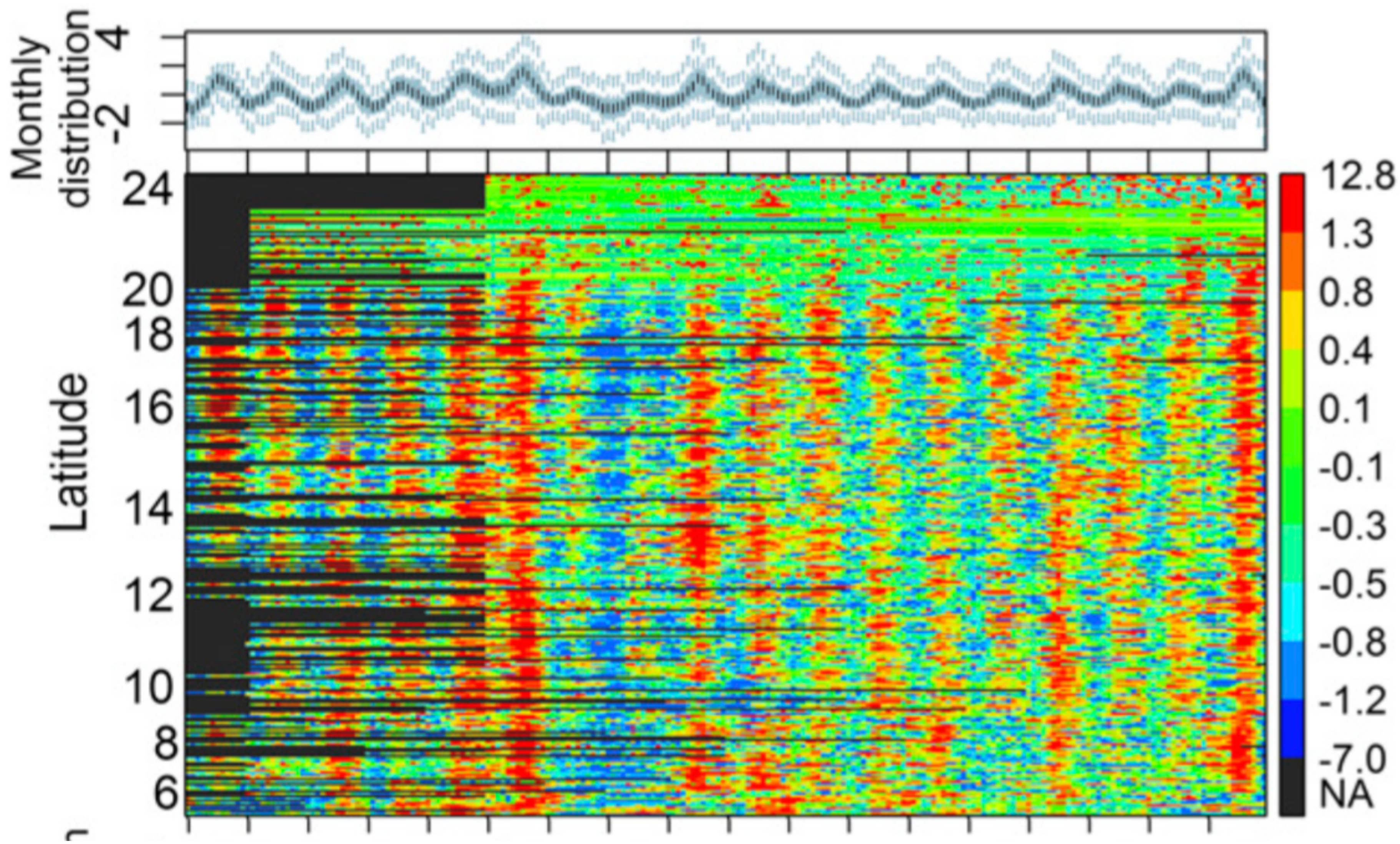
Optimal control

Model & data

Local risk factors and movements

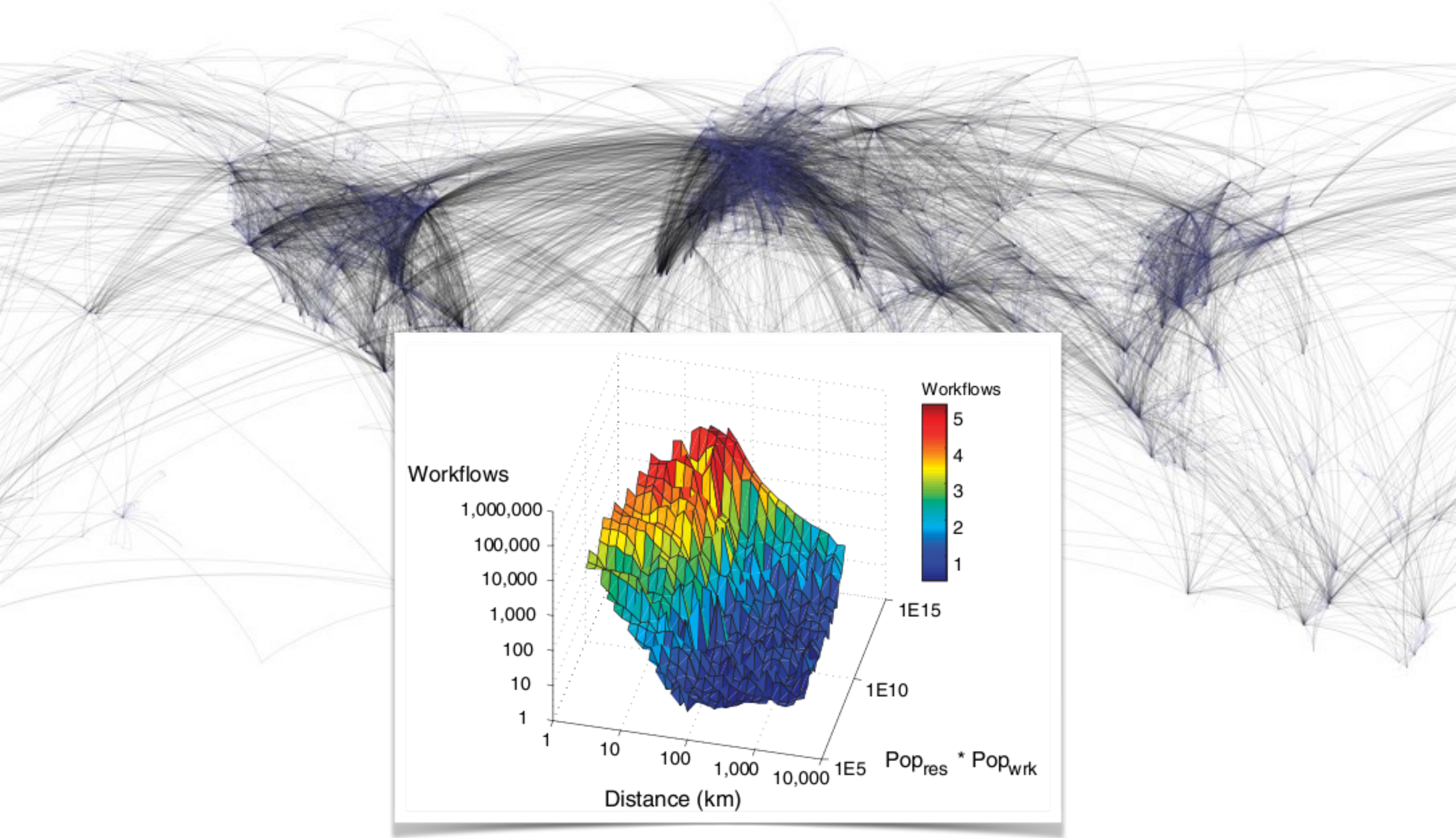


Adding the spatial dimension



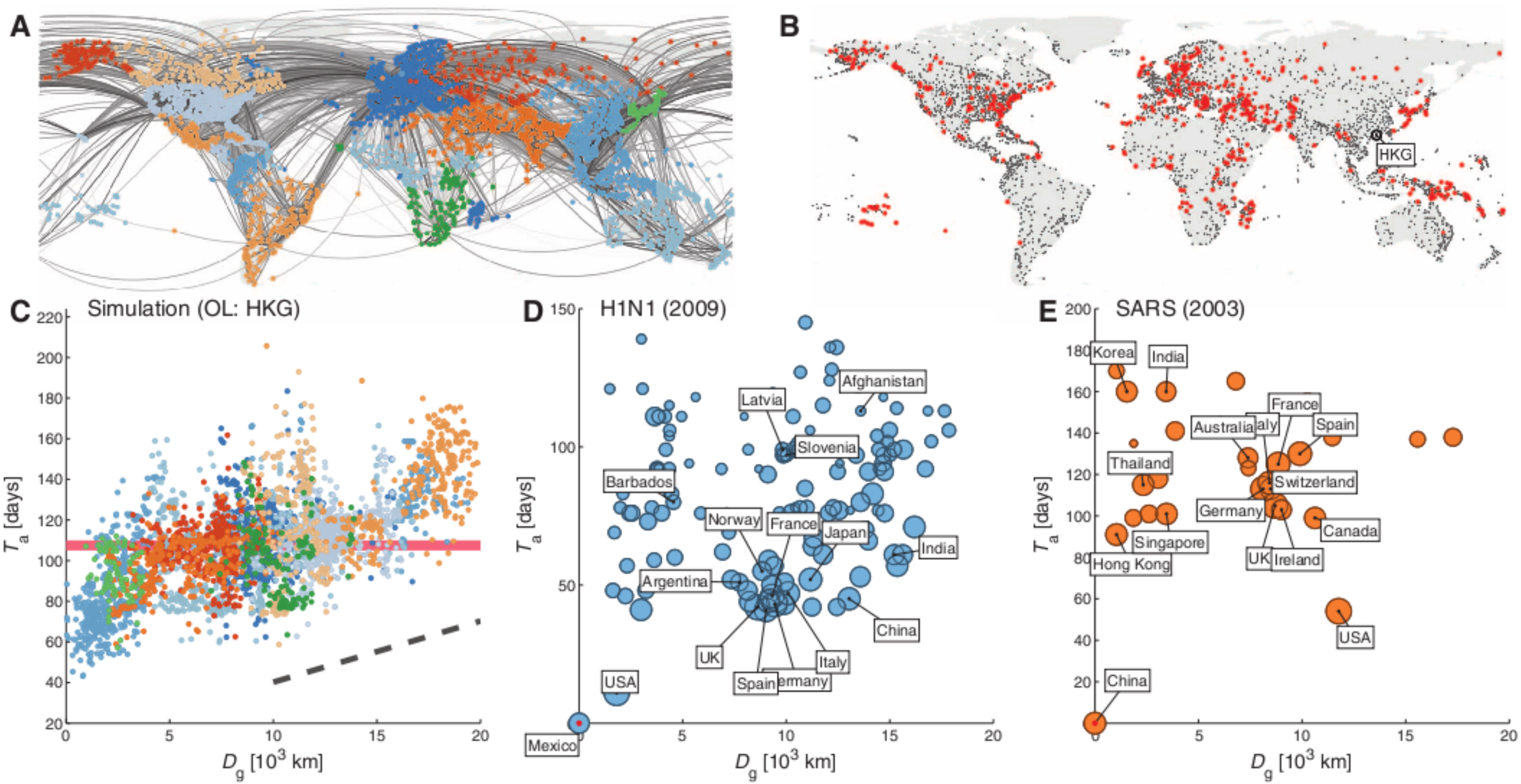
van Panhuis et al. 2015

Connections between populations



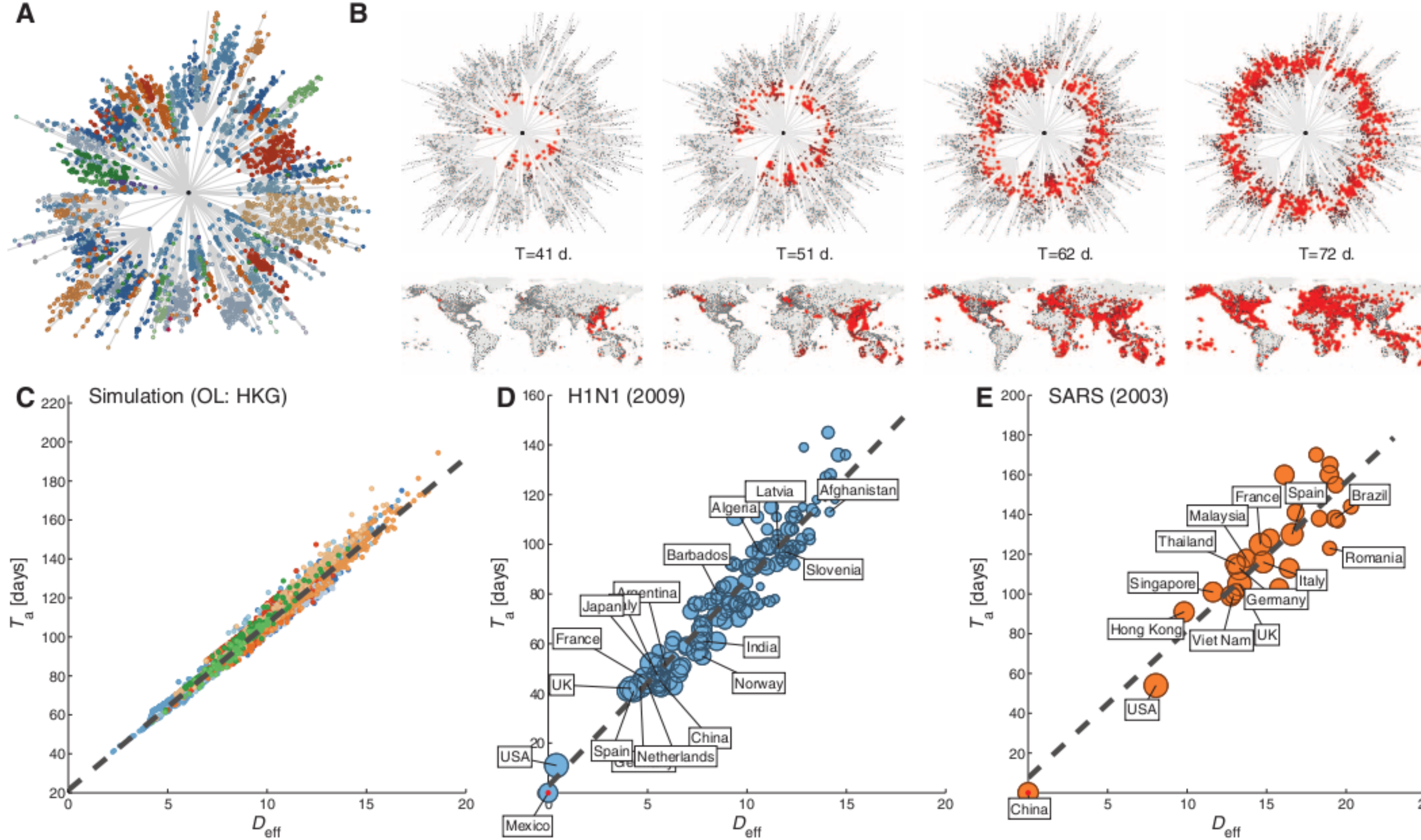
Xia et al. 2004, Viboud et al. 2006

Redefining distances



Brockmann & Helbing 2013

Redefining distances



Brockmann & Helbing 2013

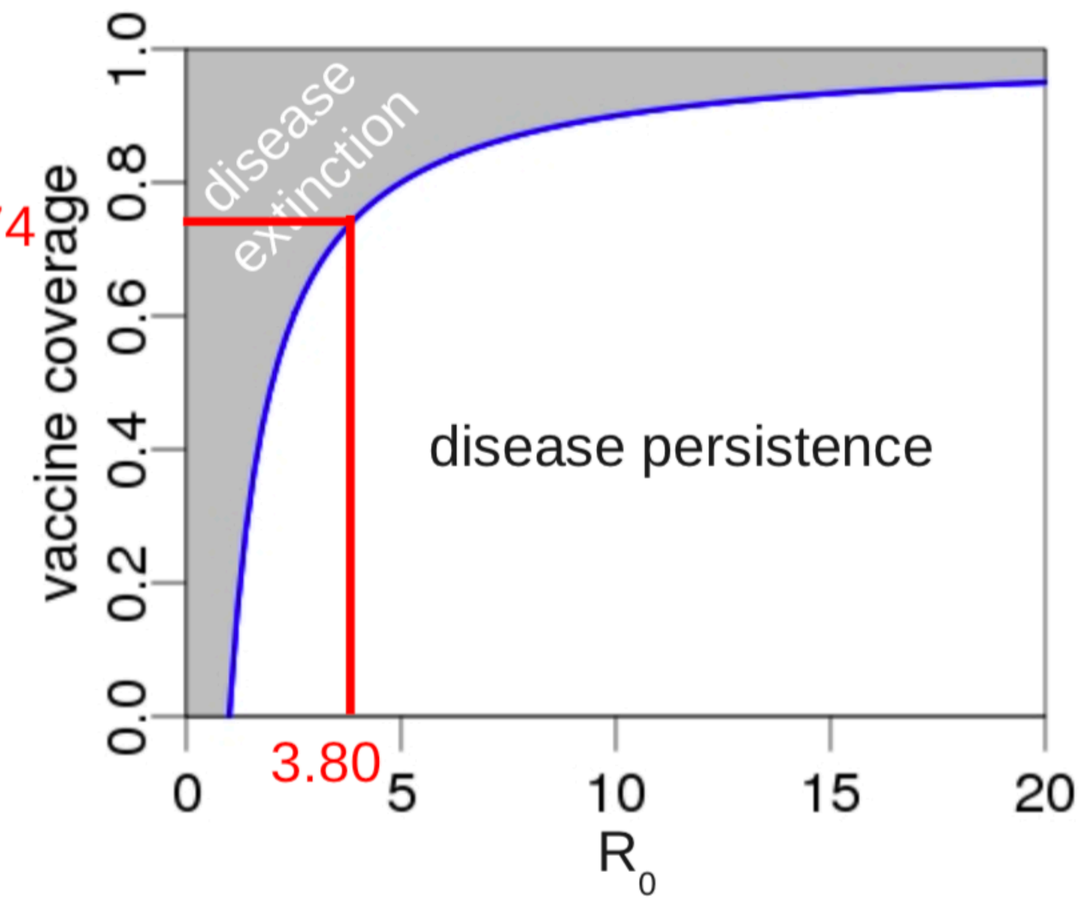
Seasonality

Spatial dynamics

Optimal control

Herd immunity

$$p_c = 1 - \frac{1}{R_0} \simeq 0.74$$



herd immunity

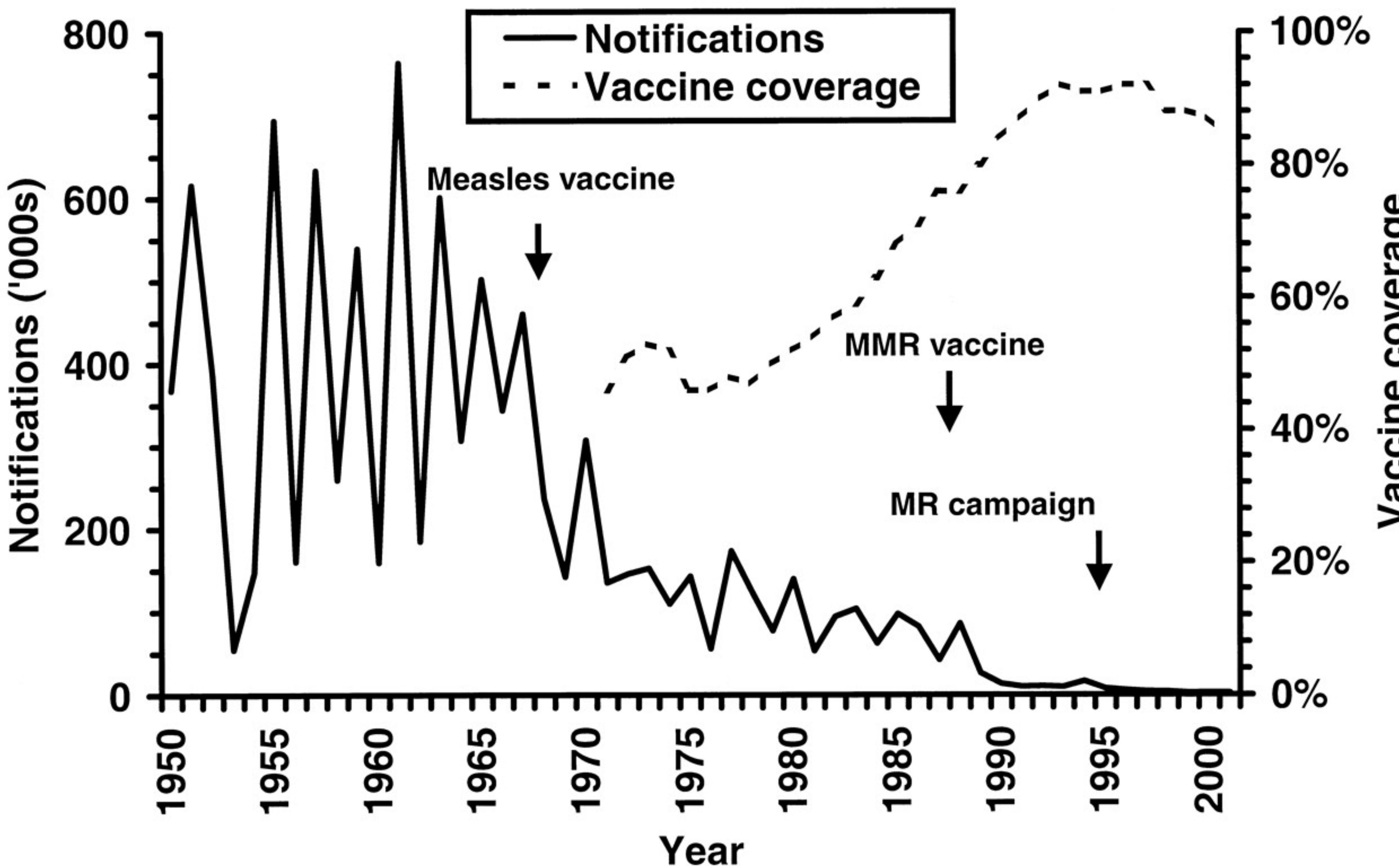
$$R_0 = \frac{\beta}{\gamma} = \frac{1.67}{0.44} = 3.80$$

Herd immunity

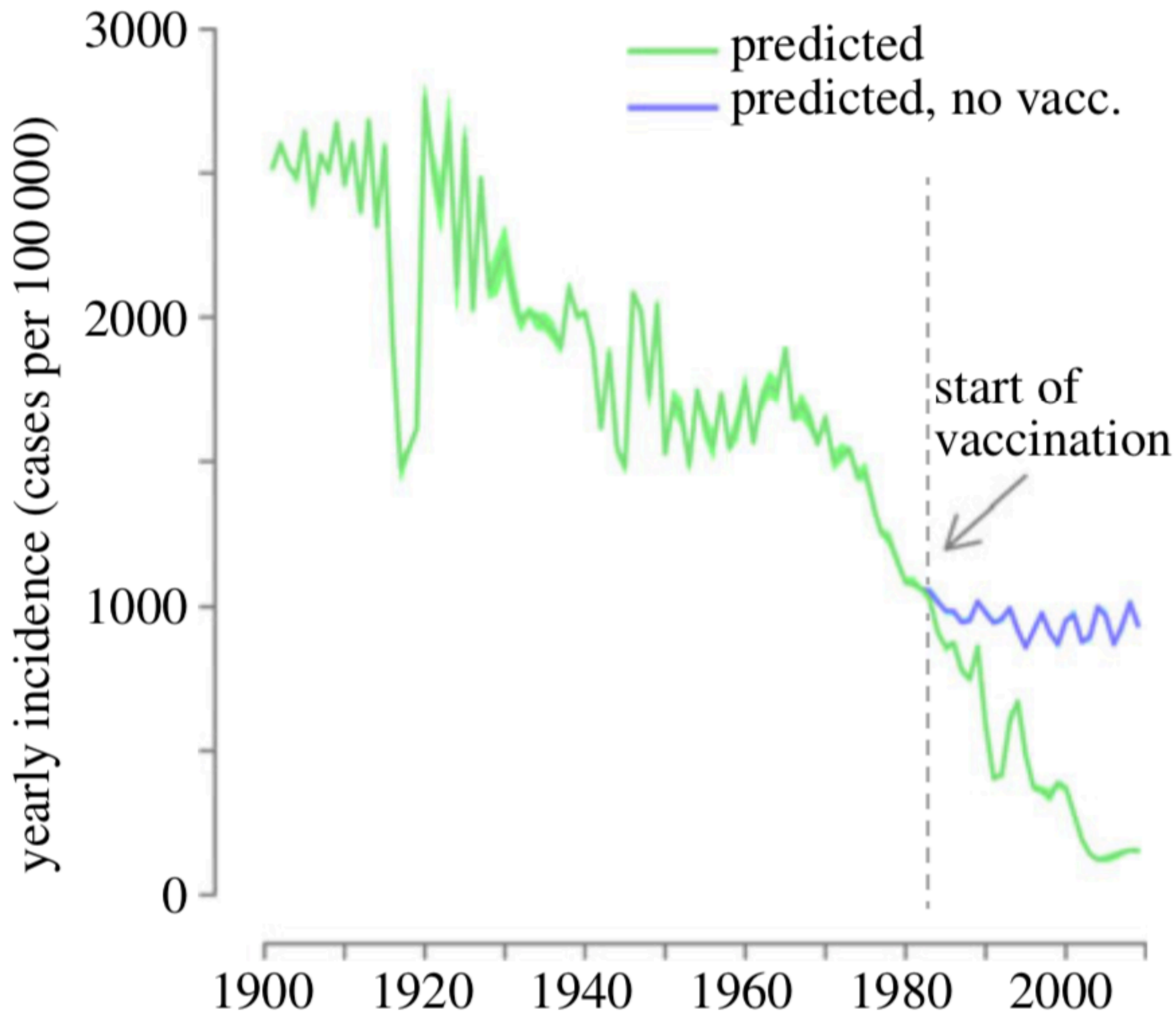
Disease	Host	R_0	p_c
tuberculosis	cattle	2.6	62%
FIV	domestic cat	1.1-1.5	9-33%
rabies	hyaenas	1.9	47%
phocine distemper	seals	2-3	50-66%
influenza	human	3-4	66-75%
foot and mouth disease	livestock	3.5-4.5	71-78%
smallpox	human	3.5-6	71-83%
rubella	human	6-7	83-86%
chickenpox	human	7-8 / 10-12	86-88% / 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 becouse
...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

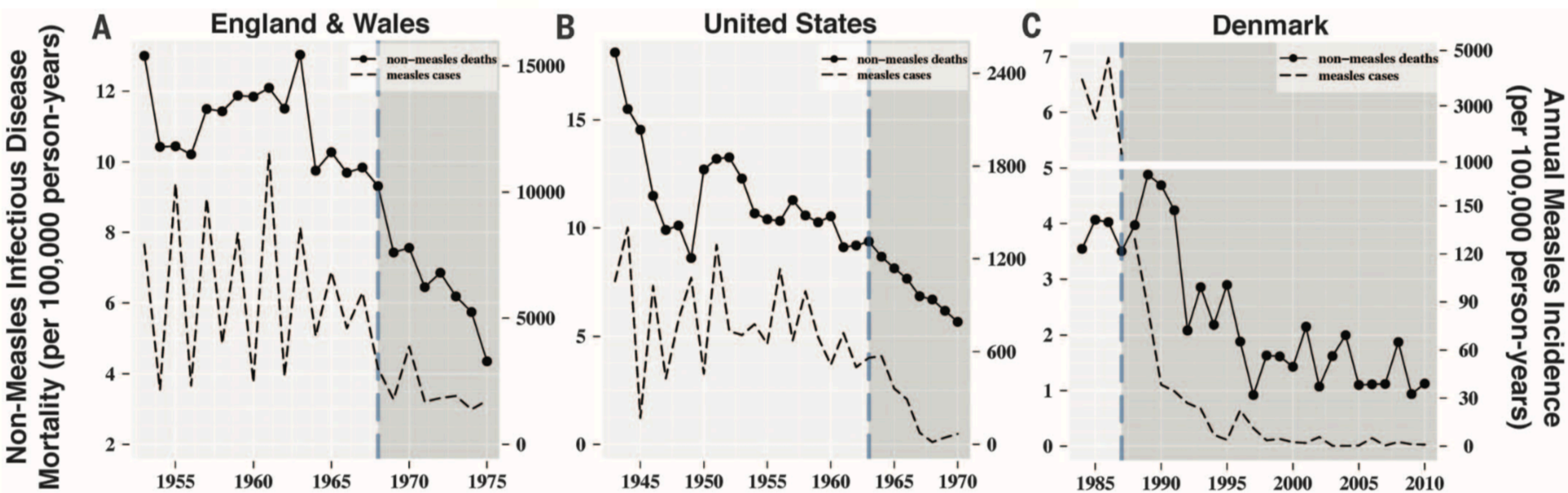


Vaccine policies: a success story



Merler et al. 2014

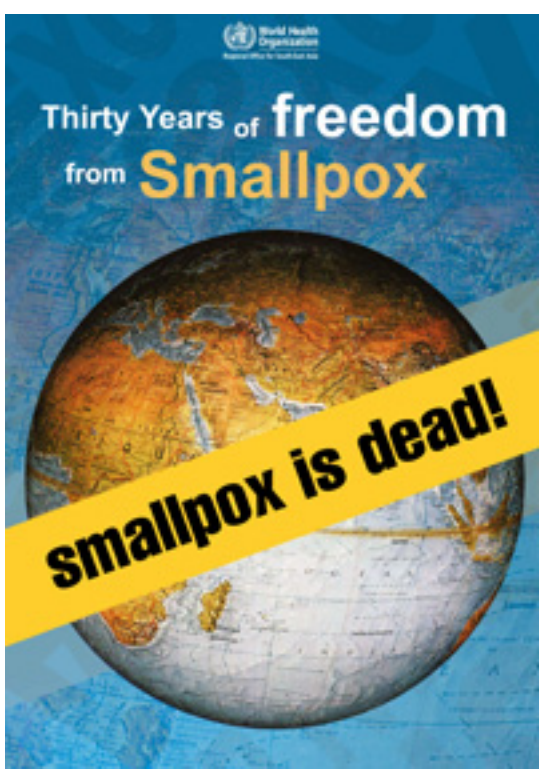
Vaccine policies: a success story

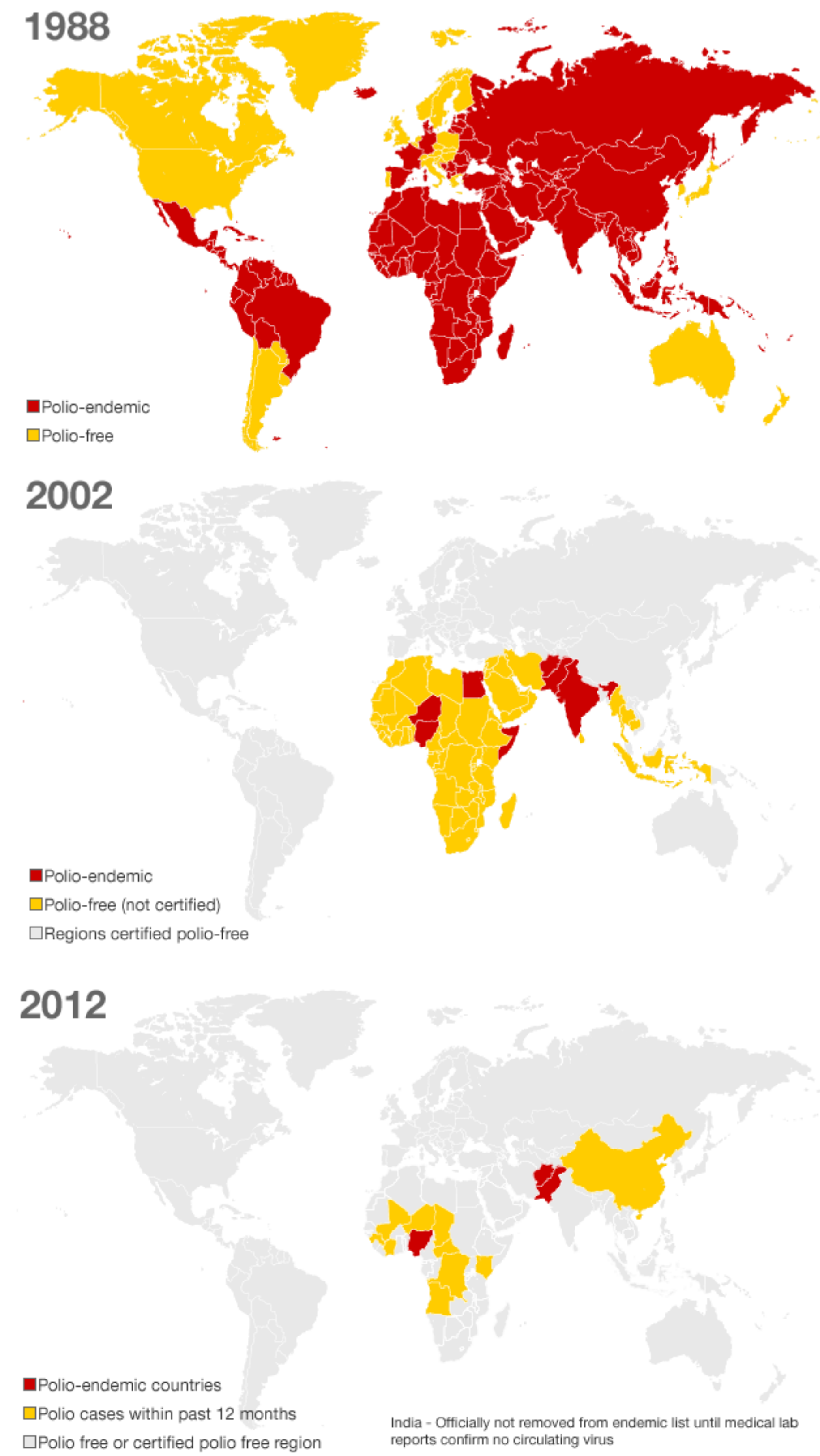


Mina et al. 2015

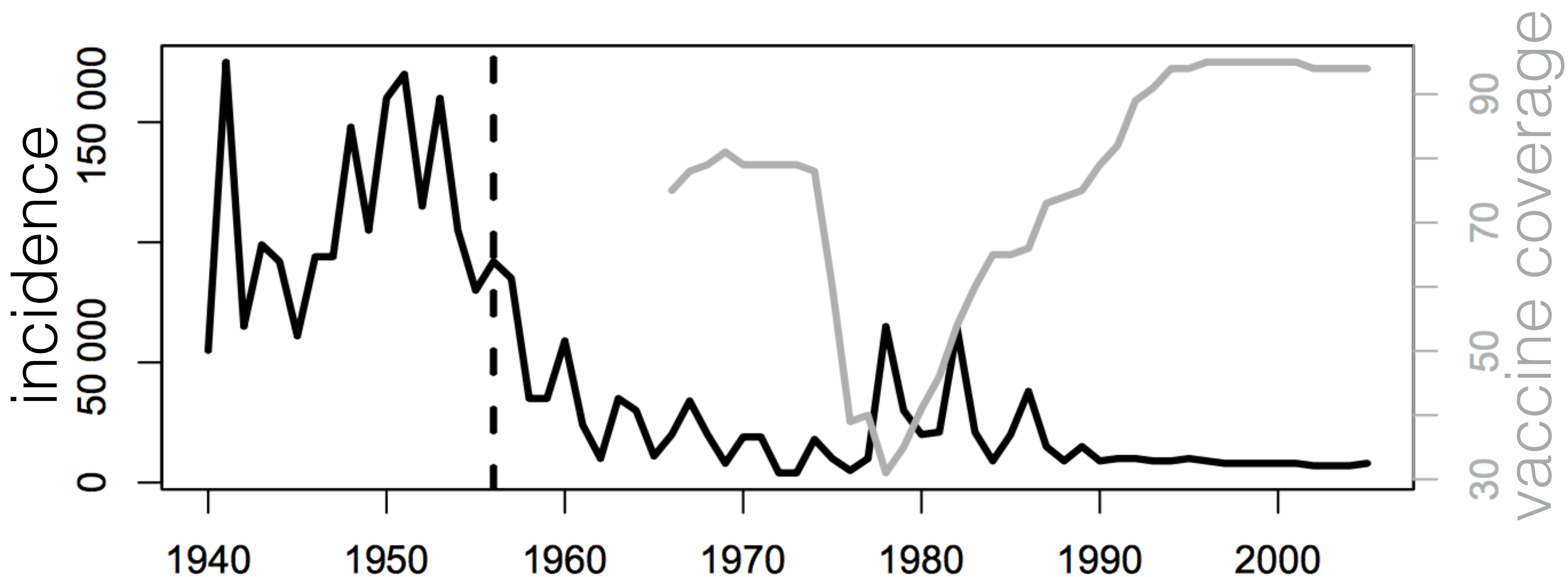
Vaccine policies: a success story

World Health Organization



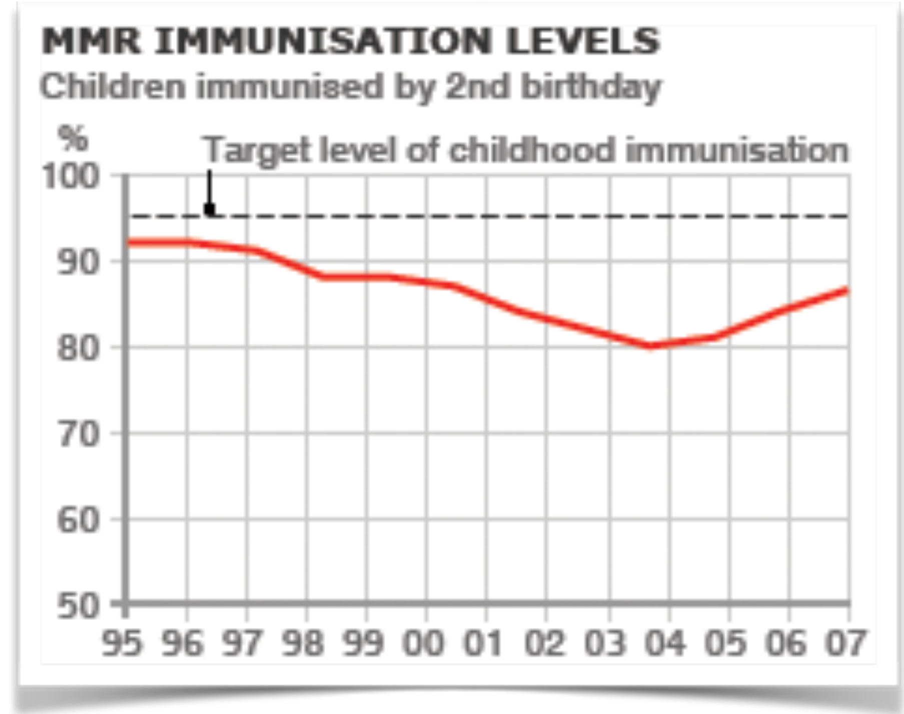


But…



incidence
0
50 000
150 000
vaccine coverage
30
50
70
90
1940
1950
1960
1970
1980
1990
2000

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 MRCPath [a], MA Thomson FRCP [b], P Harvey FRCP [d], A Valentine FRCR [e], SE Davies MRCPath [a], JA Walker-Smith FRCP [a]

Summary

Background

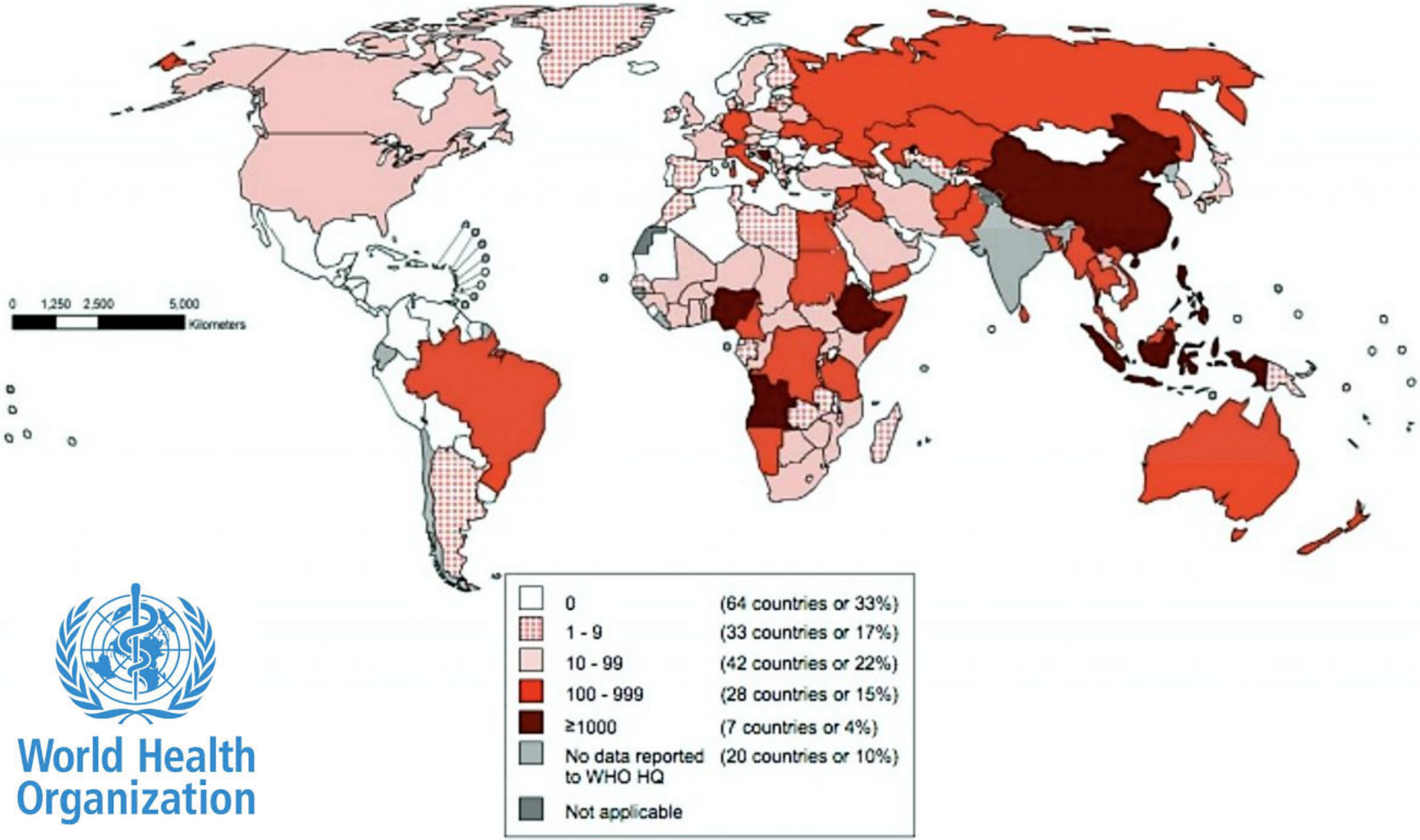
We investigated a consecutive series of children with chronic enterocolitis and regressive developmental disorder.

RETRACTED

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.

But…



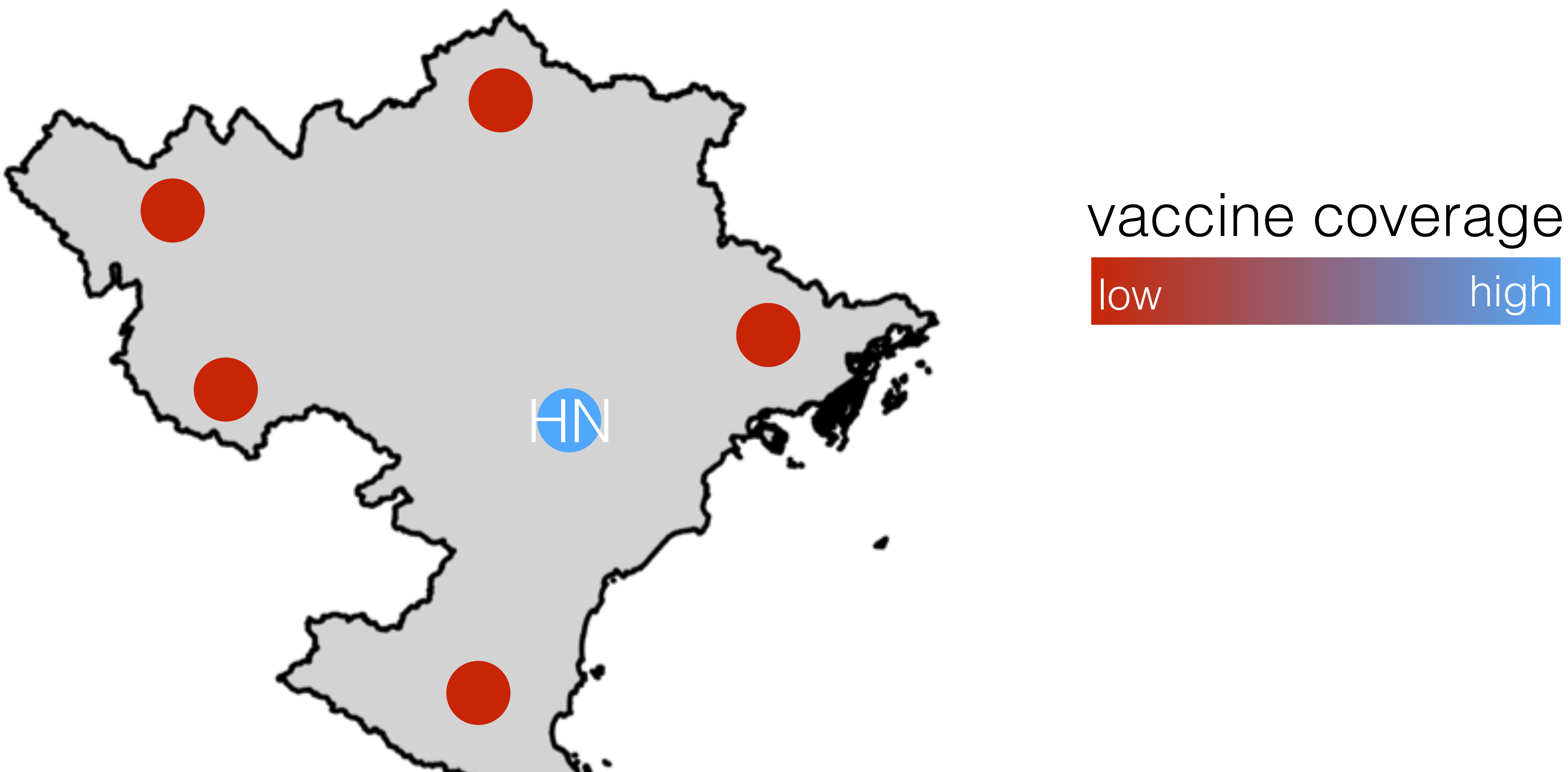
World Health Organization

Consequences of vaccination

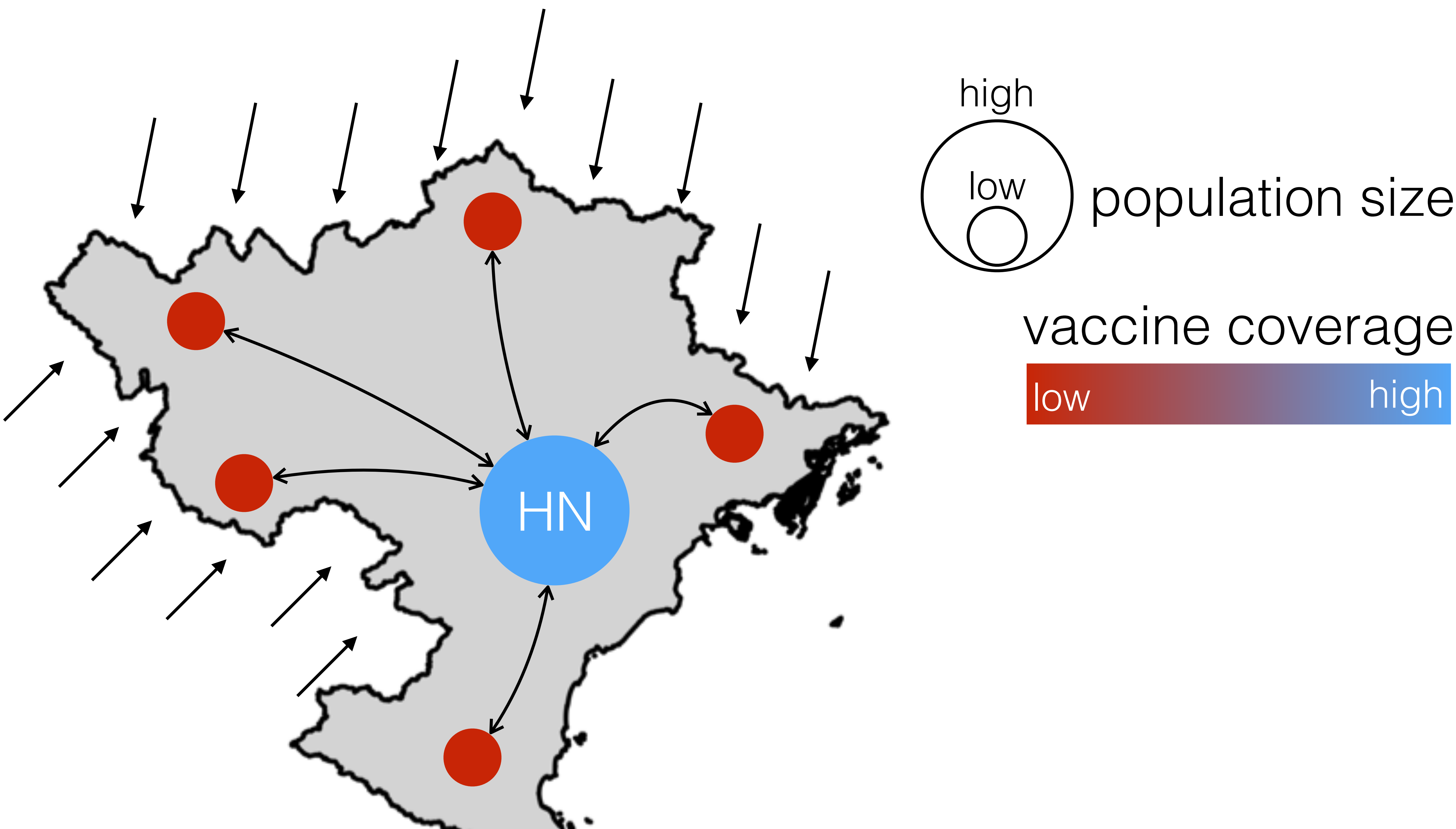
Consequences of vaccination

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

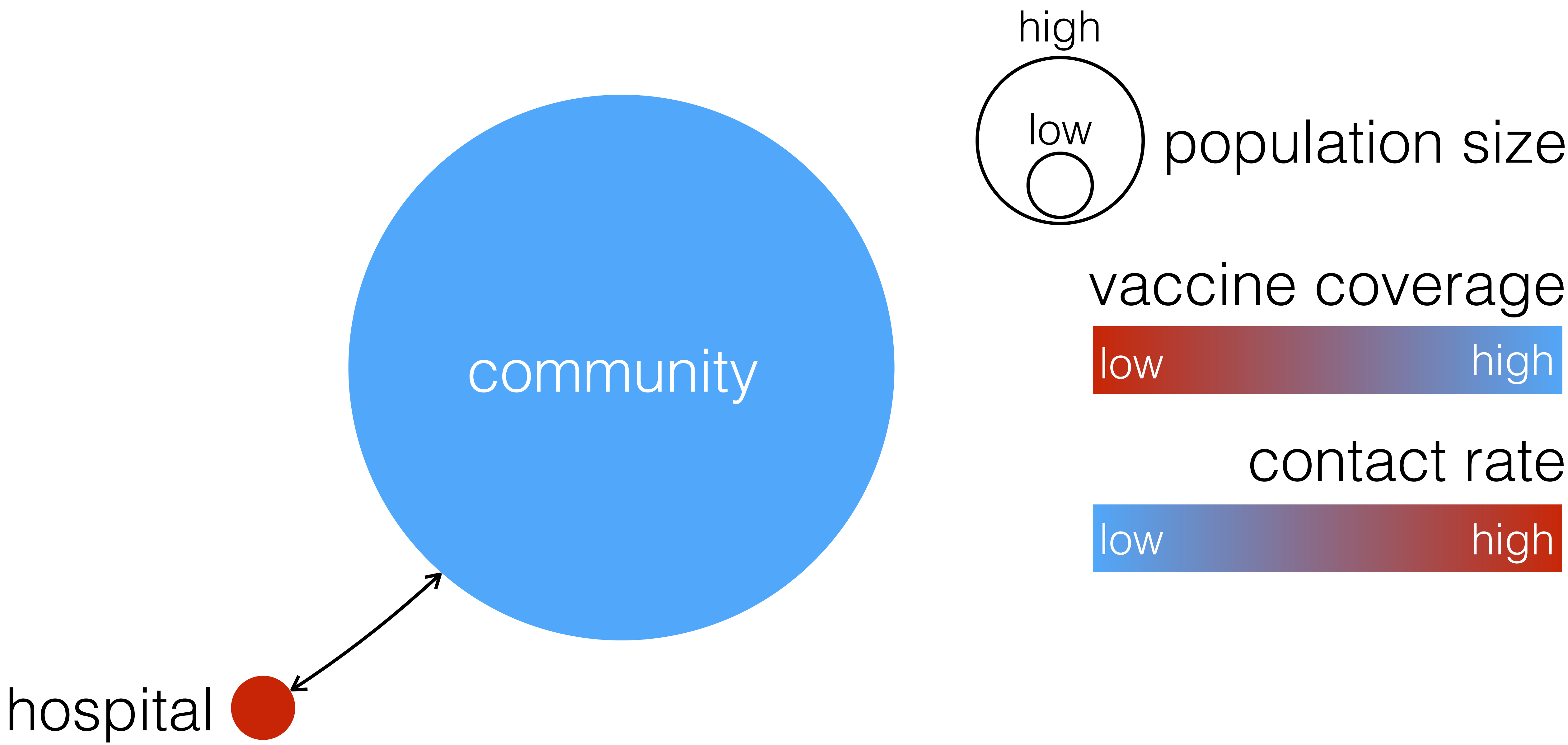
Measles in northern Vietnam



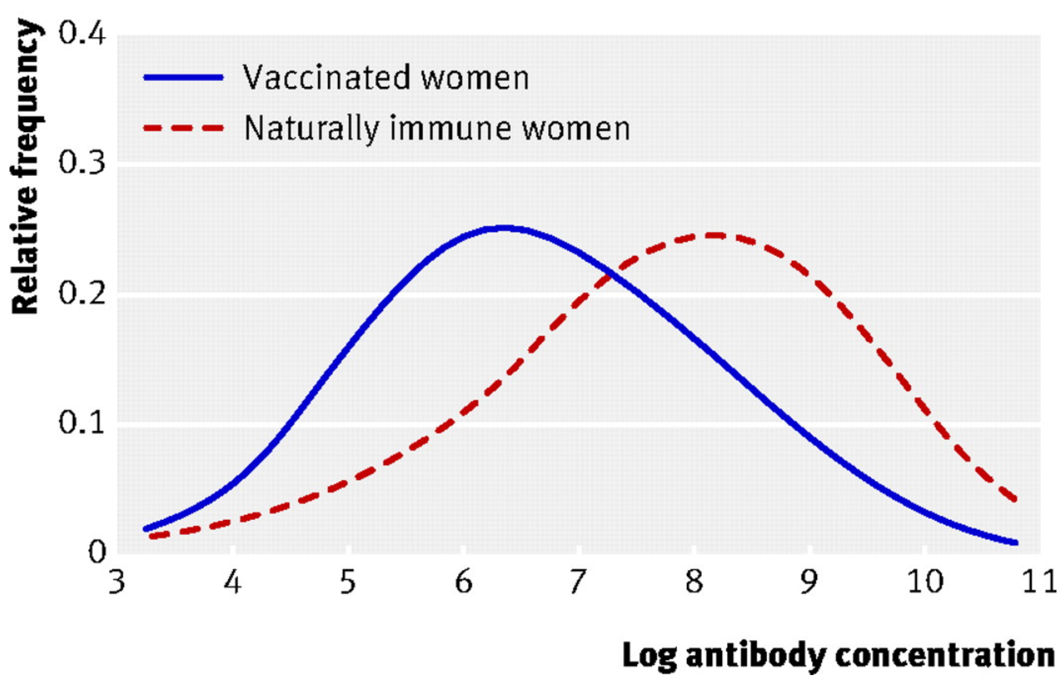
Measles in northern Vietnam

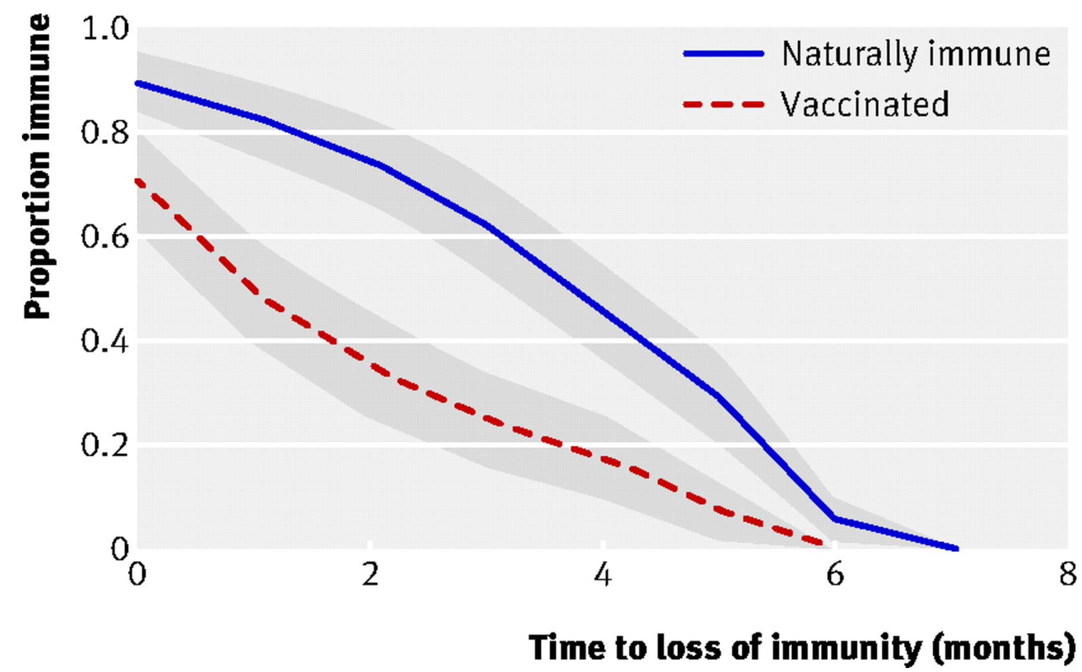


Measles in northern Vietnam

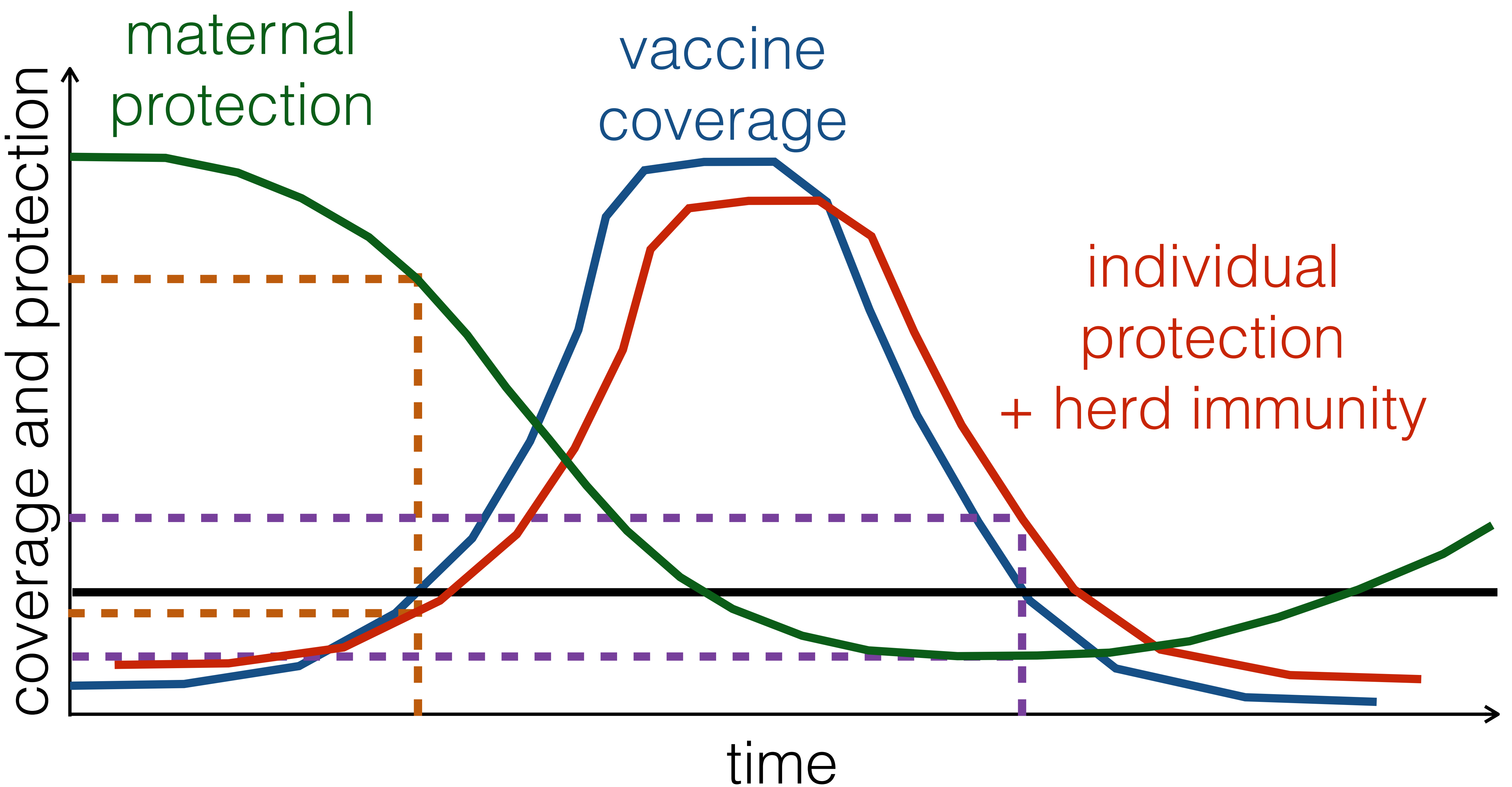


Maternal protection





Leuridan et al. 2010


maternal protection
vaccine coverage
individual protection + herd immunity
coverage and protection
time

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