Value of modeling in the Transmission Dynamics of Arbovirus

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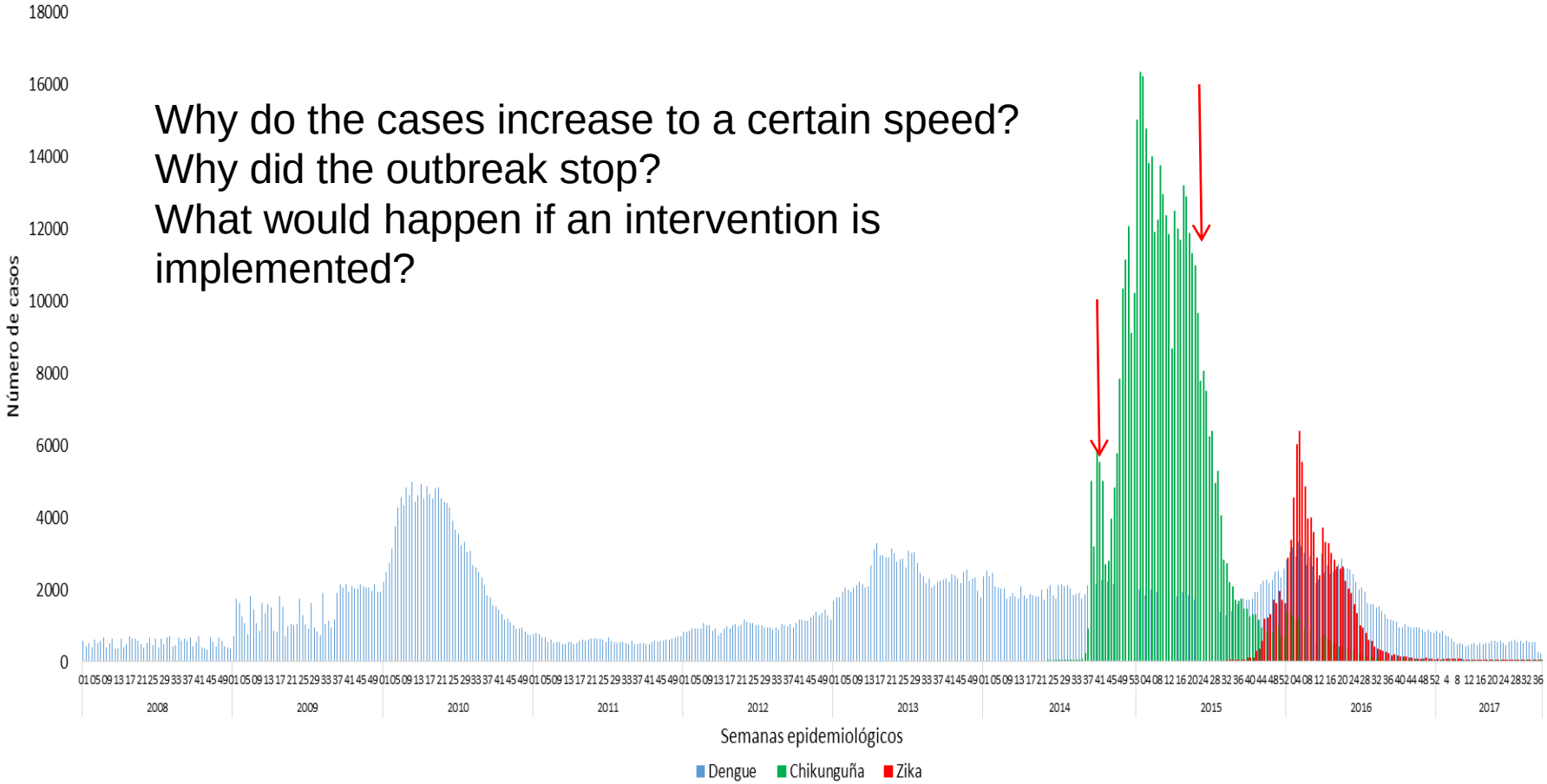
What is Infectious Disease Dynamics?

- The study of contagion
- Who gets infected, by whom, at what rates? What are the impacts of control measures?
- Interested in temporal progression (dynamics)

Why understand transmission dynamics?

- Know the scale of the epidemic
  - Number of people involved
  - Spatial scale (how big of an area might be affected?)
  - Temporal scale (how long will it last?)
- Be able to evaluate the impact of interventions
  - Is the epidemic speeding up or slowing down?
  - Where should we devote more resources to control?

TRENDS OF ARBOVIRAL DISEASES, COLOMBIA 2008-2017*



**** A semana epidemiológica 37 de 2017***

Fuente: Sivigila 2017. Instituto Nacional de Salud, equipo ETV Zoonosis.
Presentacion PAHO Octubre 2017.

Iceberg of Arboviral infections

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Applications of transmission dynamics in arbovirus

ART OF MODELING

Leonardo da Vinci

Fernando Botero

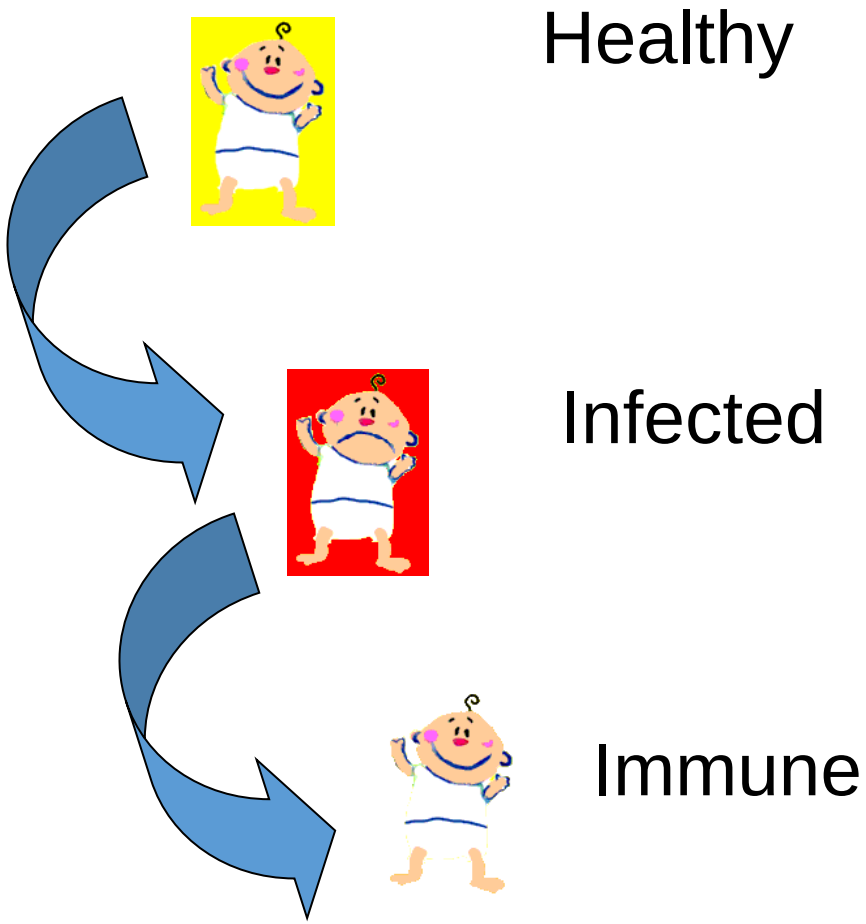
Dana Maloney

Modeling:

reality

abstraction,
conceptualization

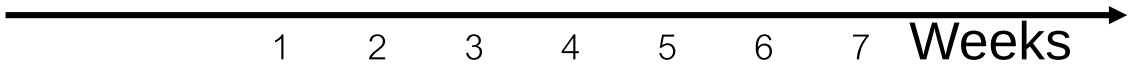
Transmission of infectious diseases



Modified from Ralph Frerichs, UCLA (http://www.ph.ucla.edu/epi/200/epi200_01.html)

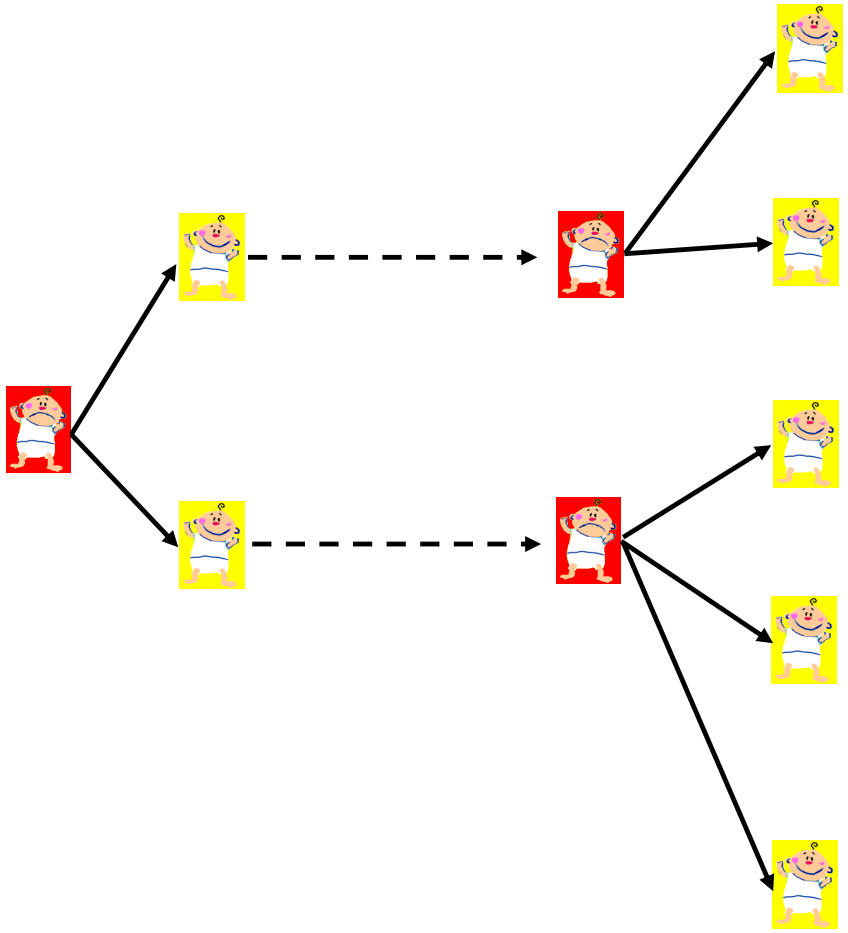
If the infected child gets in contact with others, How many will get infected? Sick? How long would it take?

If the transmission occurs, which factors of the transmission process are more important determining the speed of spread?



Modified from Ralph Frerichs, UCLA (http://www.ph.ucla.edu/epi/200/epi200_01.html)

What does determine the incidence rate of an infectious disease?



At least two things affect the speed of the spread of an outbreak?

1. The number of people infected by each infected individual

2. The time that it takes between one person gets infected and when it is able to infect others.

R_0 estimations of different pathogens

Sarampion – 12

Tosferina – 15

Varicela – 9

Difteria – 4

Parotiditis – 10

Rubeola – 8

Polio – 6

Viruela – 6

Influenza – 2

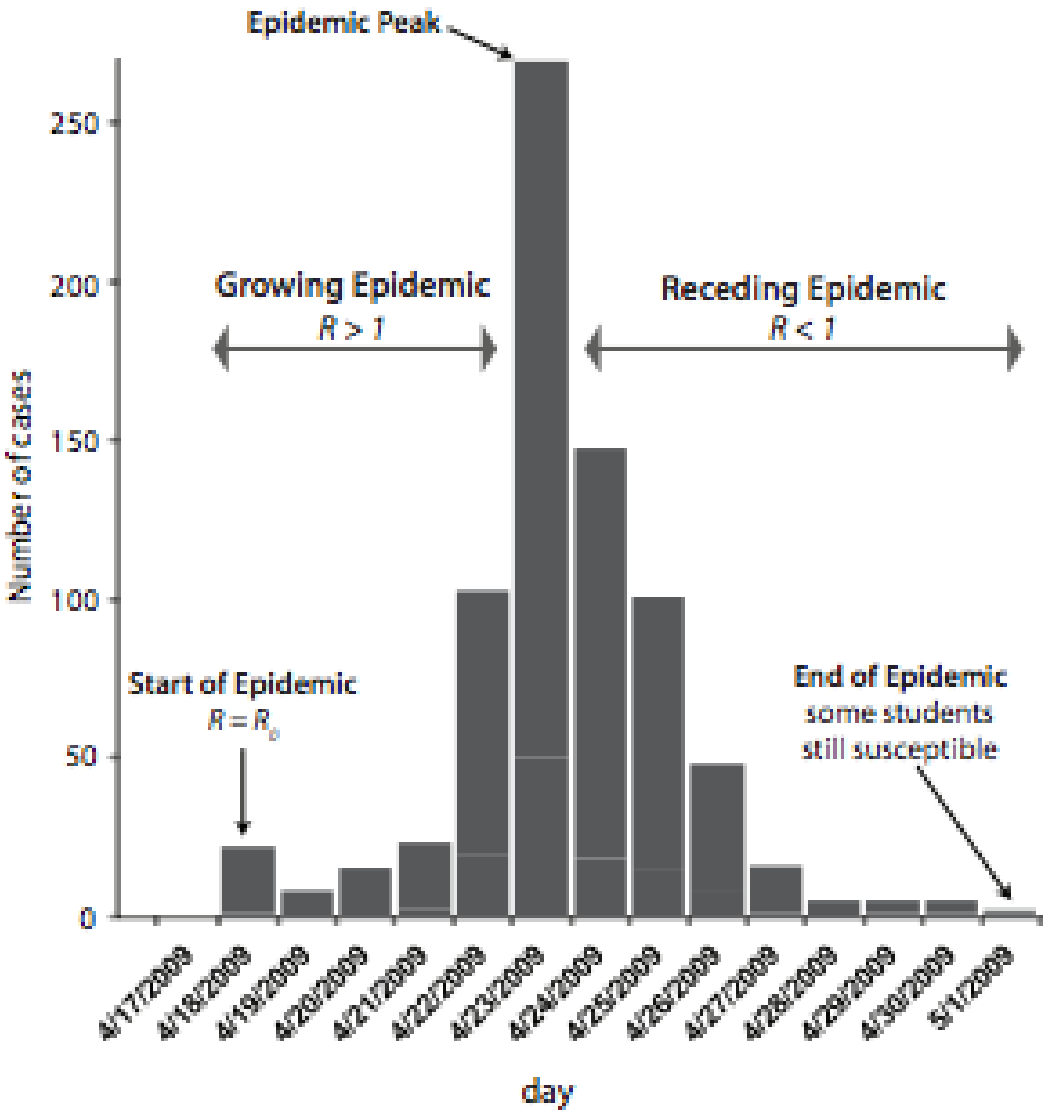
HIV – 5

Dengue – 4

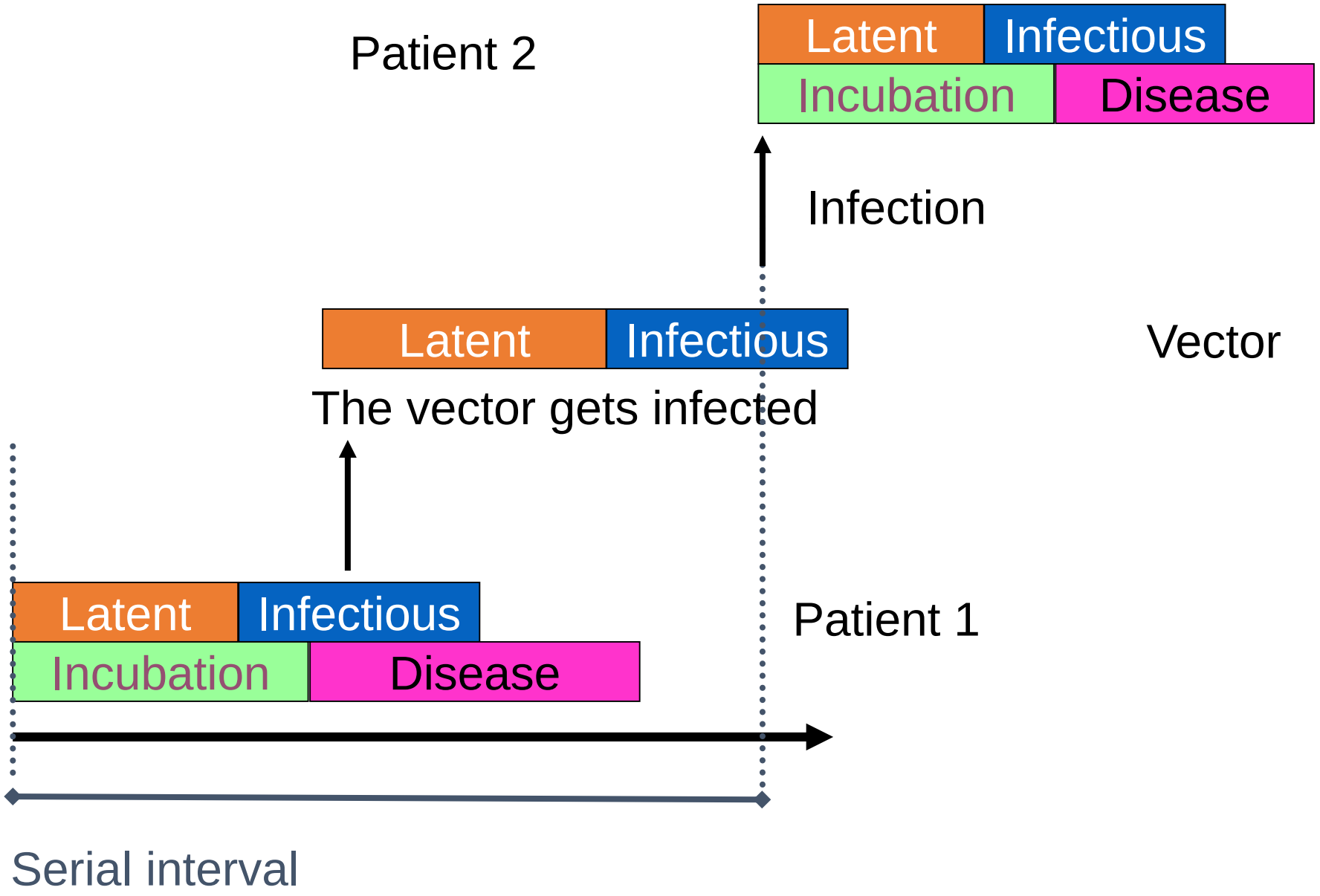
R_0 is specific for each pathogen and each setting (depends on the population density, social factors)

Anderson and May, 1991

R and epidemic curve



Which is the R_0 in this case?

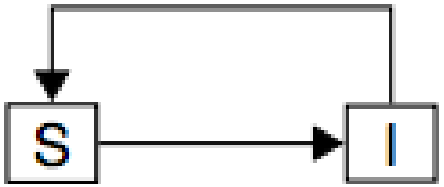

Patient 2
Latent
Infectious
Incubation
Disease
Infection
Latent
Infectious
Vector
The vector gets infected
Latent
Infectious
Incubation
Disease
Patient 1
Serial interval

Compartmental models

SIR:

SEIR:

SIS:



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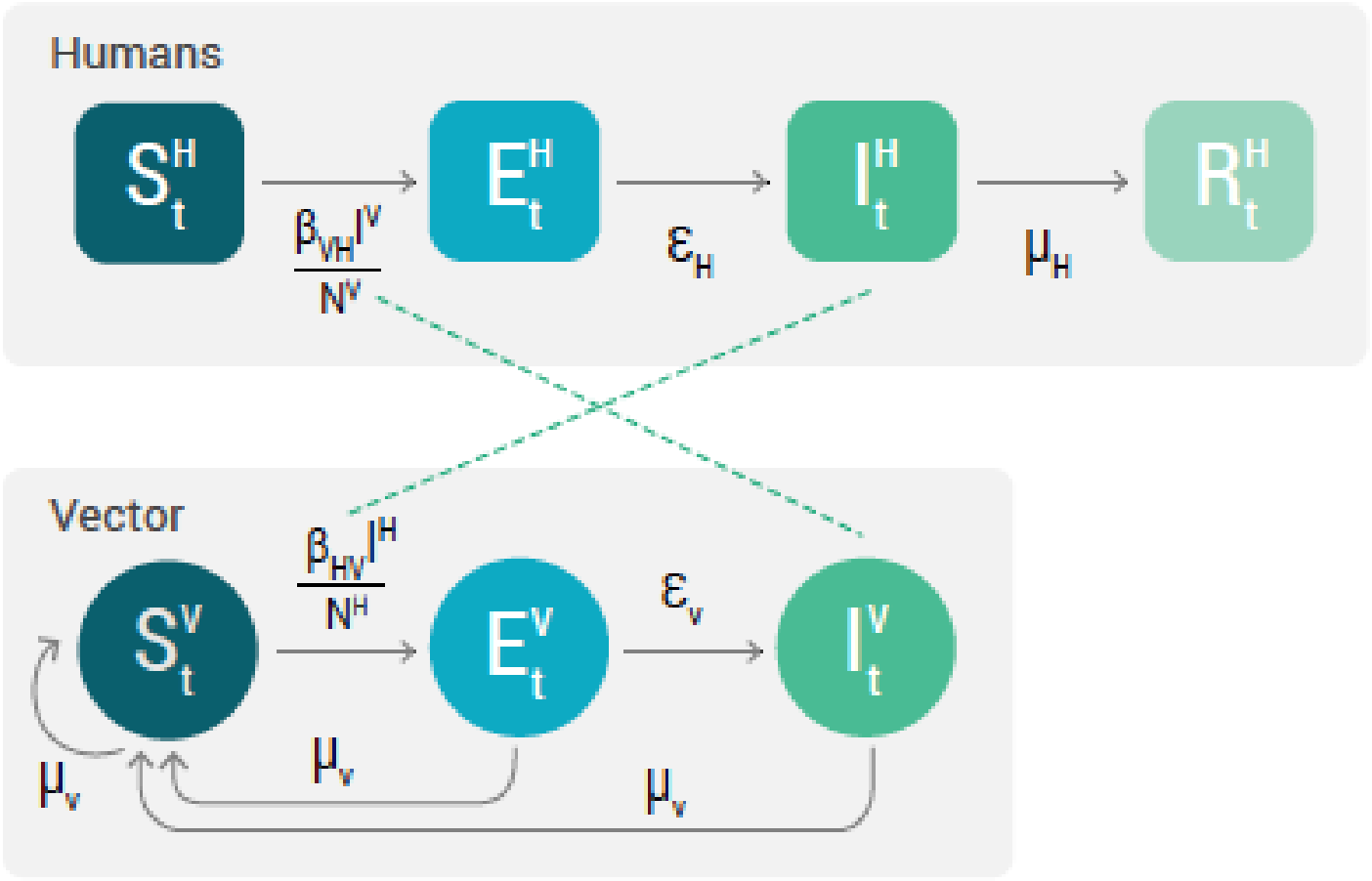
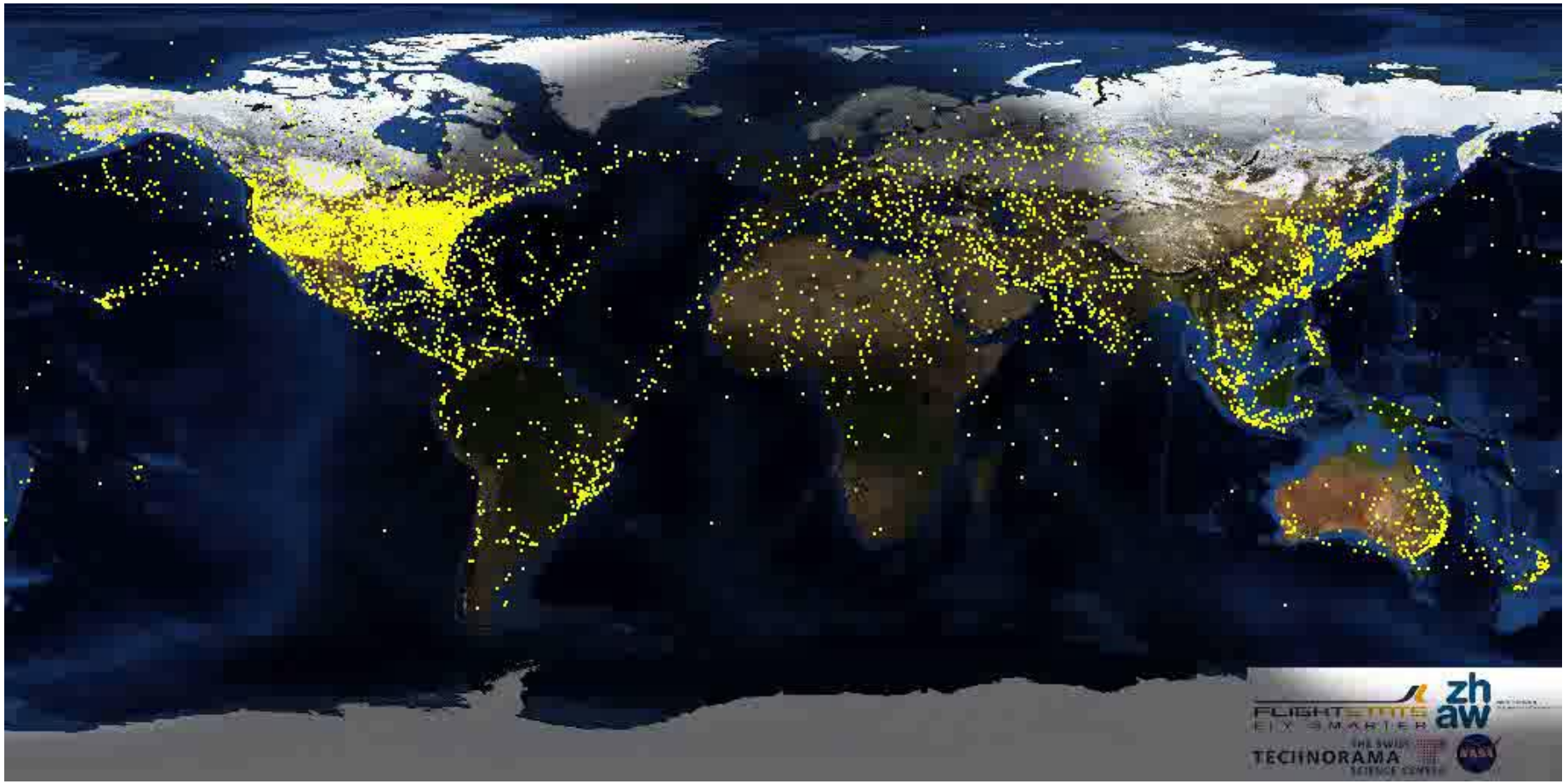
Spread of Zika virus in the Americas

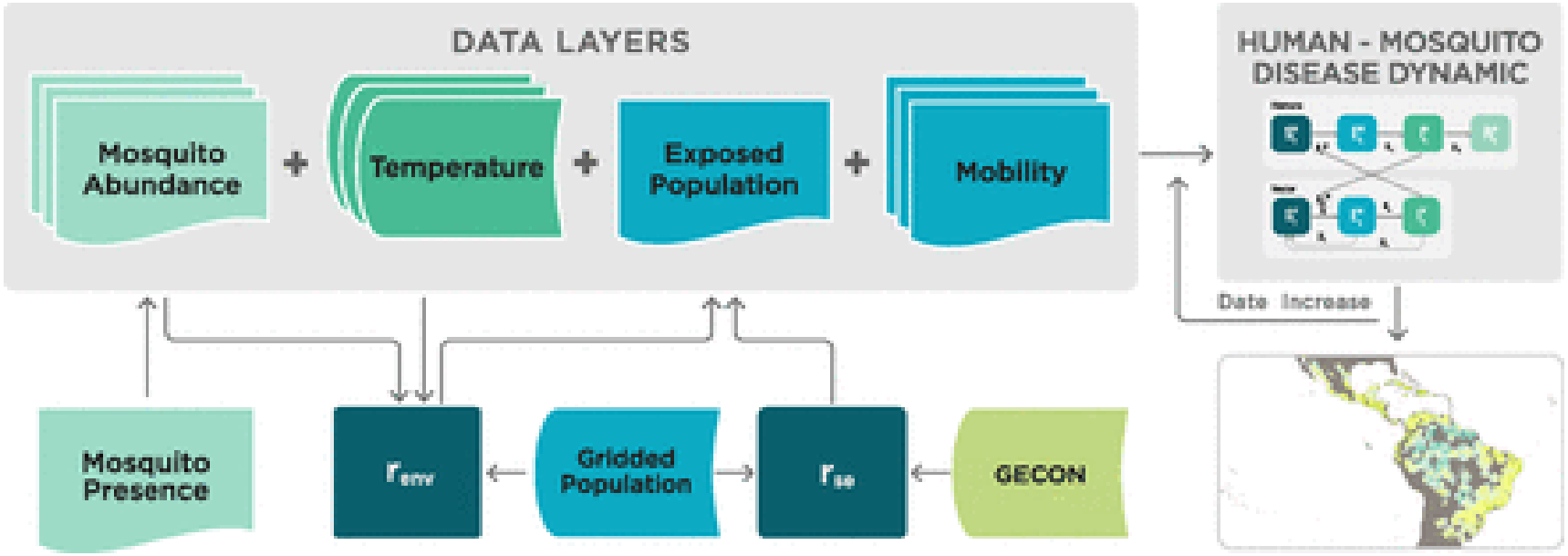
Zhang, Q., Sun, K., Chinazzi, M., y Piontti, A. P., Dean, N. E., Rojas, D. P., ... & Bray, M. (2017). Spread of Zika virus in the Americas. *Proceedings of the National Academy of Sciences*, *114*(22), E4334-E4343.

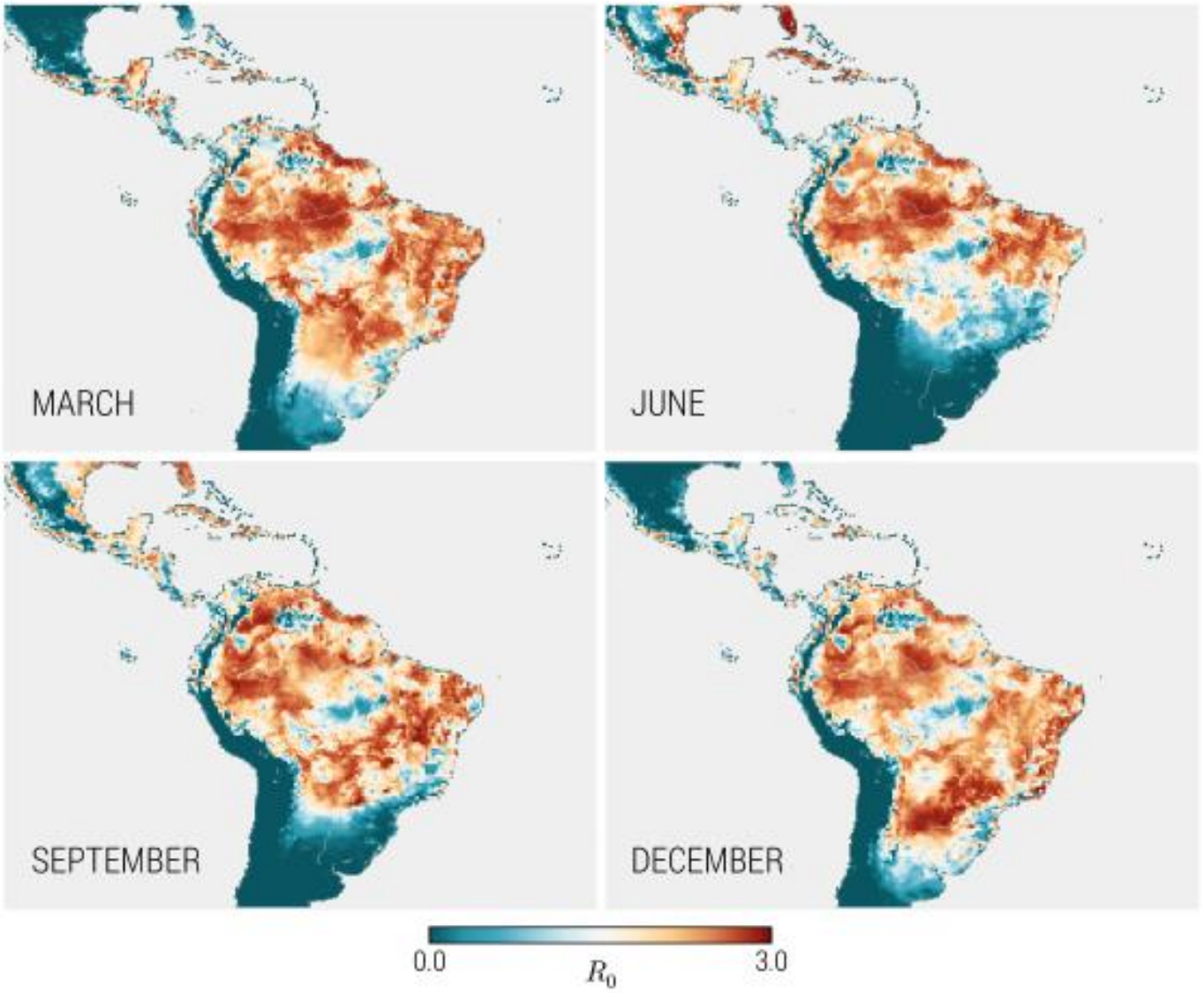

Humans
S_t^H
$\frac{\beta_{VH} I^V}{N^V}$
E_t^H
ε_H
I_t^H
μ_H
R_t^H
Vector
$\frac{\beta_{HV} I^H}{N^H}$
S_t^V
E_t^V
ε_v
I_t^V
μ_v
μ_v
μ_v

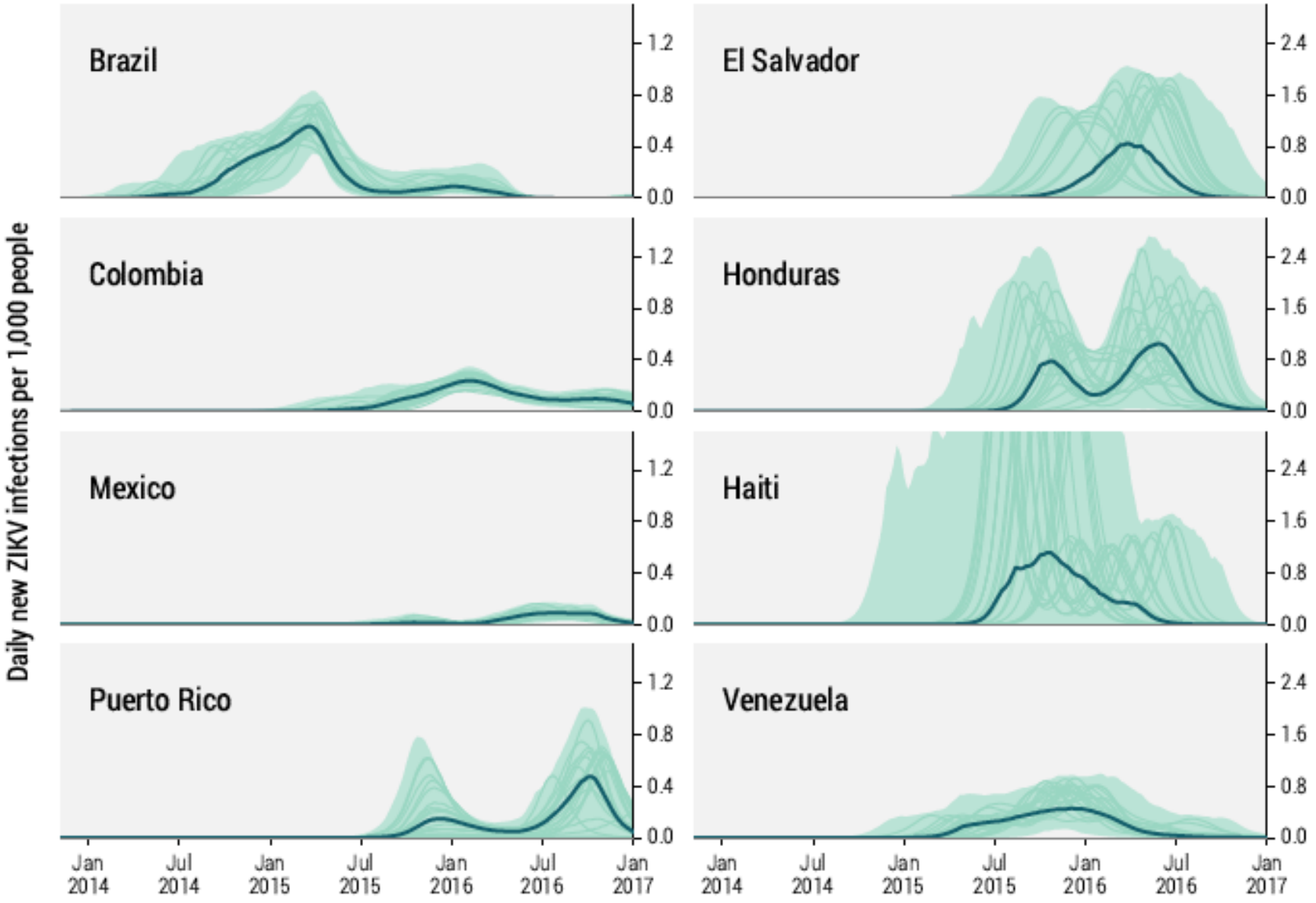
Human Population Movement

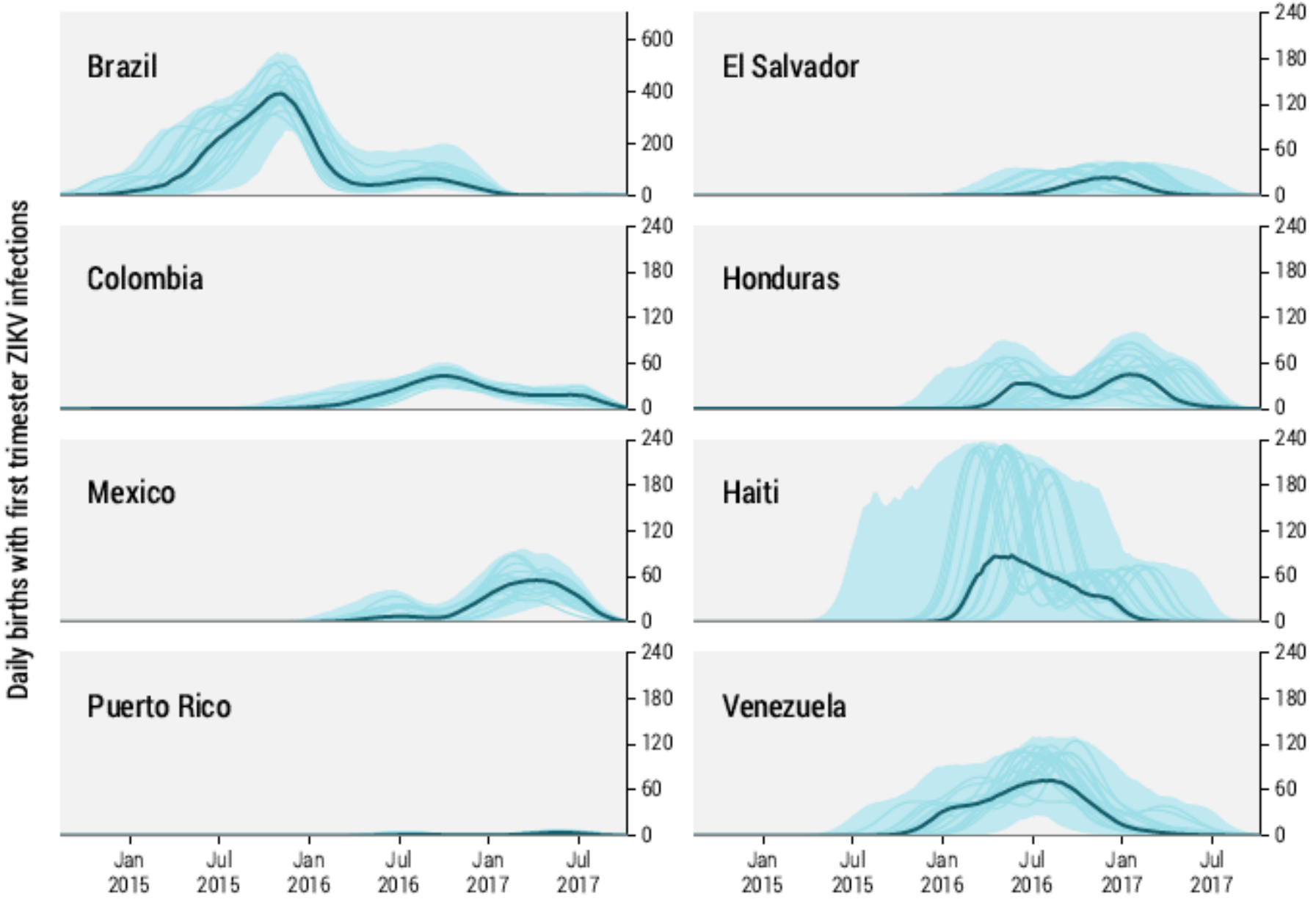


24 Hour Global Air Traffic Simulation
http://radar.zhaw.ch/resources/airtraffic.wmv


DATA LAYERS
Mosquito Abundance
Temperature
Exposed Population
Mobility
HUMAN - MOSQUITO DISEASE DYNAMIC
Data Increase
Mosquito Presence
r_{env}
Gridded Population
r_{se}
GECON


MARCH
JUNE
SEPTEMBER
DECEMBER
0.0
3.0
R_0


Brazil
El Salvador
Colombia
Honduras
Mexico
Haiti
Puerto Rico
Venezuela
Daily new ZIKV infections per 1,000 people
0.0
0.4
0.8
1.2
1.6
2.4
Jan 2014
Jul 2014
Jan 2015
Jul 2015
Jan 2016
Jul 2016
Jan 2017



http://www.zika-model.org/

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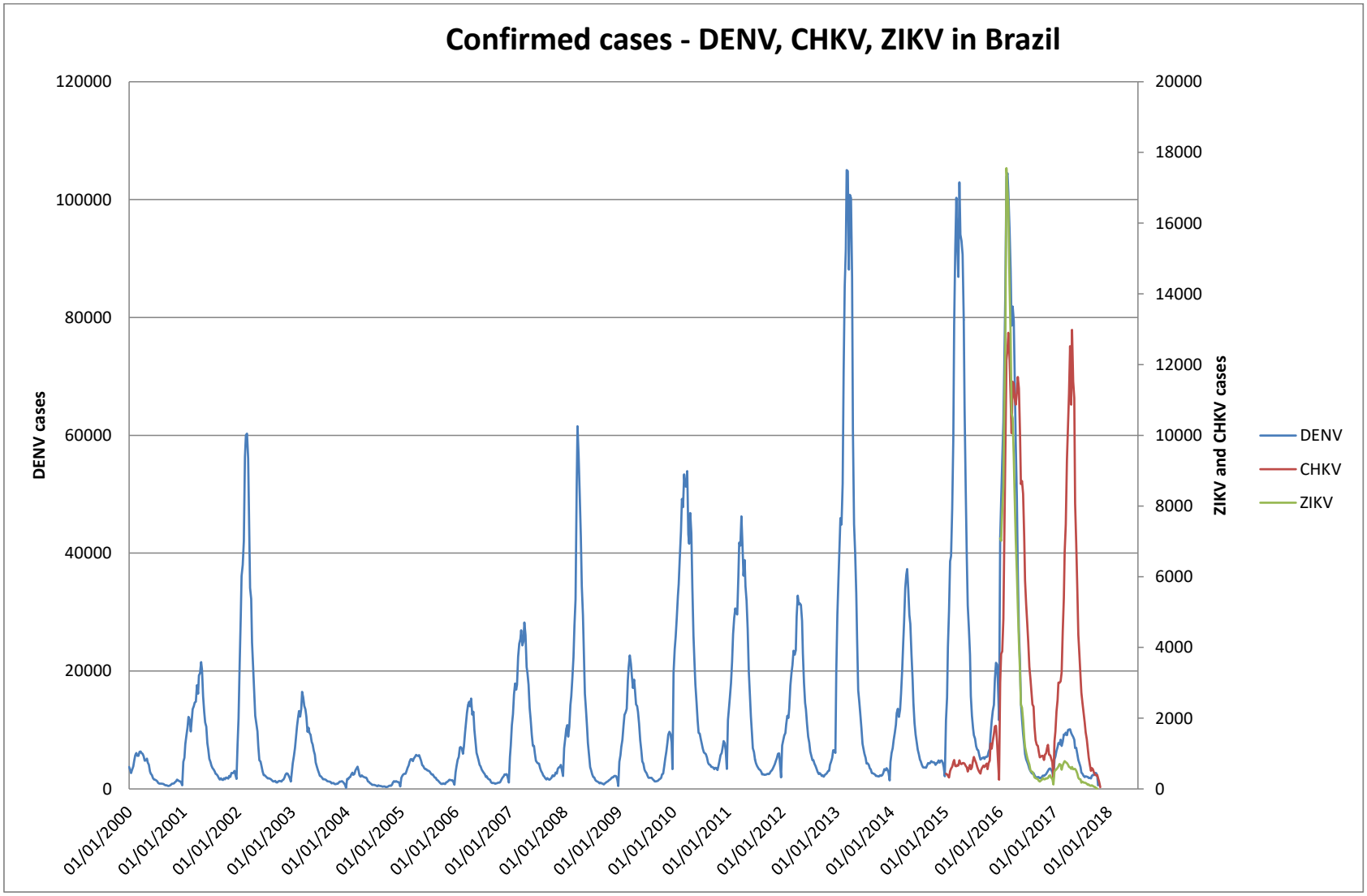
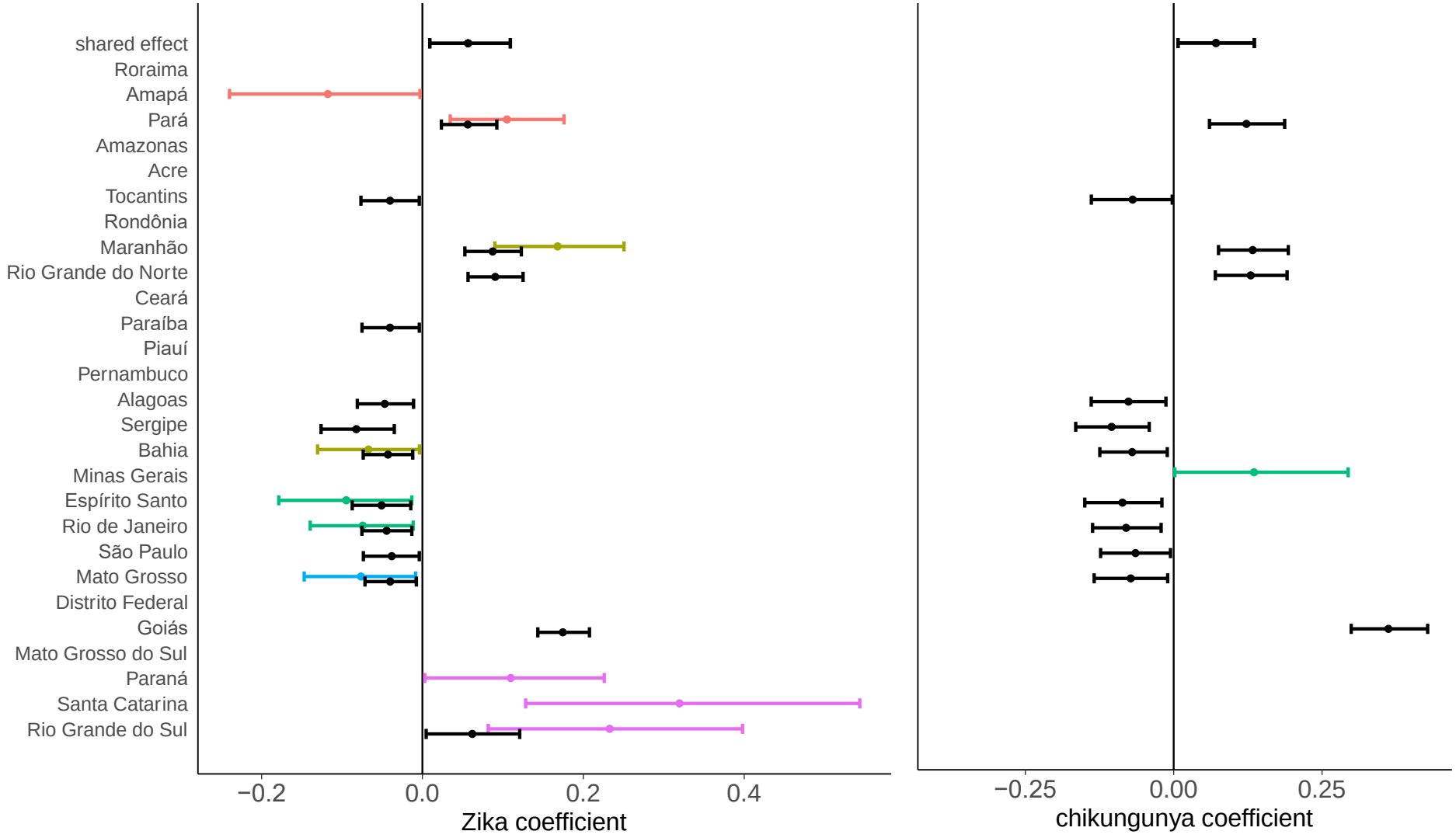
Exploratory analysis

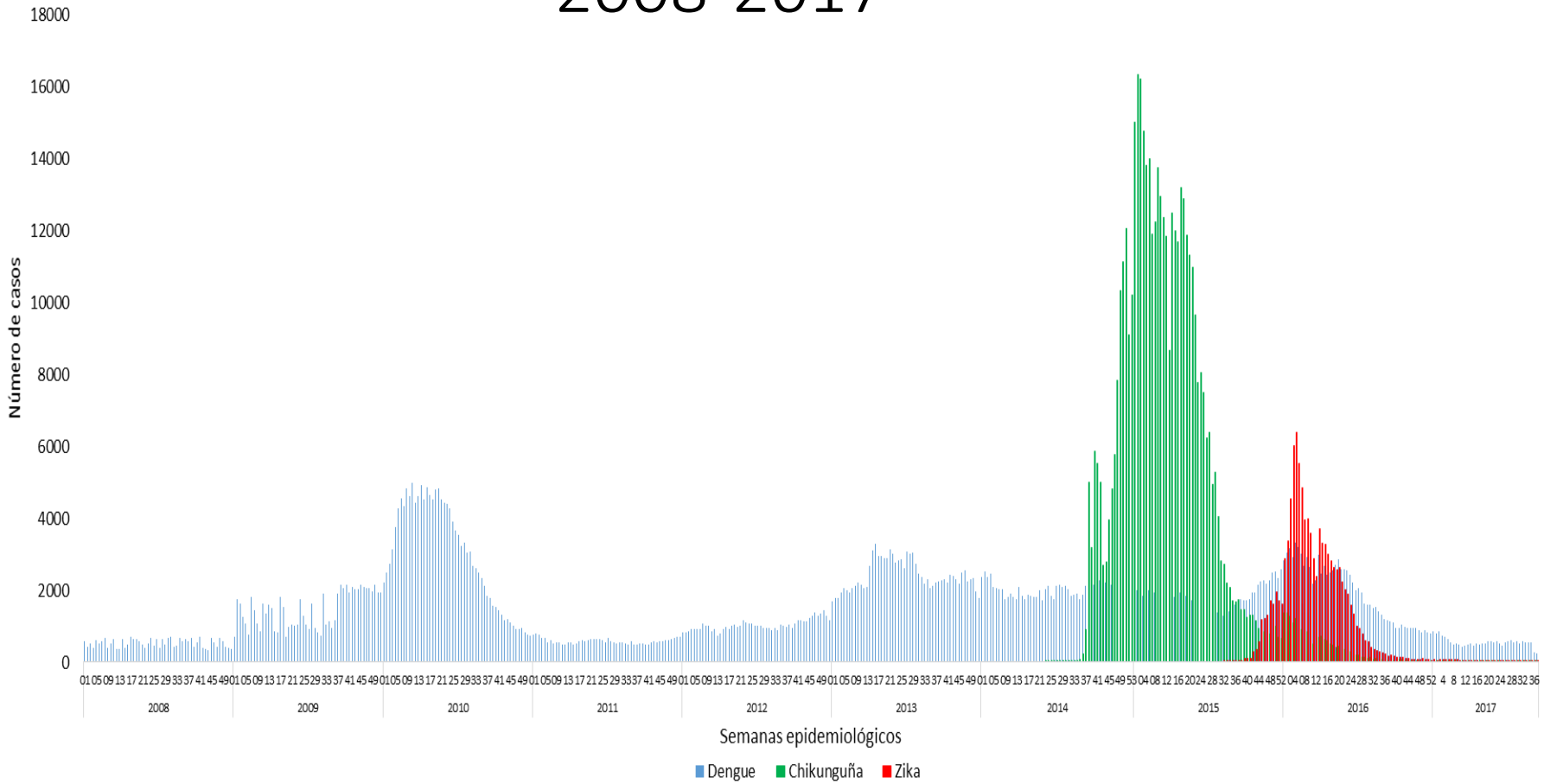
Did the introduction of ZIKV impact DENV transmission in the Americas?


Confirmed cases - DENV, CHKV, ZIKV in Brazil
DENV cases
ZIKV and CHKV cases
120000
100000
80000
60000
40000
20000
0
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
01/01/2000
01/01/2001
01/01/2002
01/01/2003
01/01/2004
01/01/2005
01/01/2006
01/01/2007
01/01/2008
01/01/2009
01/01/2010
01/01/2011
01/01/2012
01/01/2013
01/01/2014
01/01/2015
01/01/2016
01/01/2017
01/01/2018
DENV
CHKV
ZIKV

ZIKV-CHIKV coefficients-Brazil



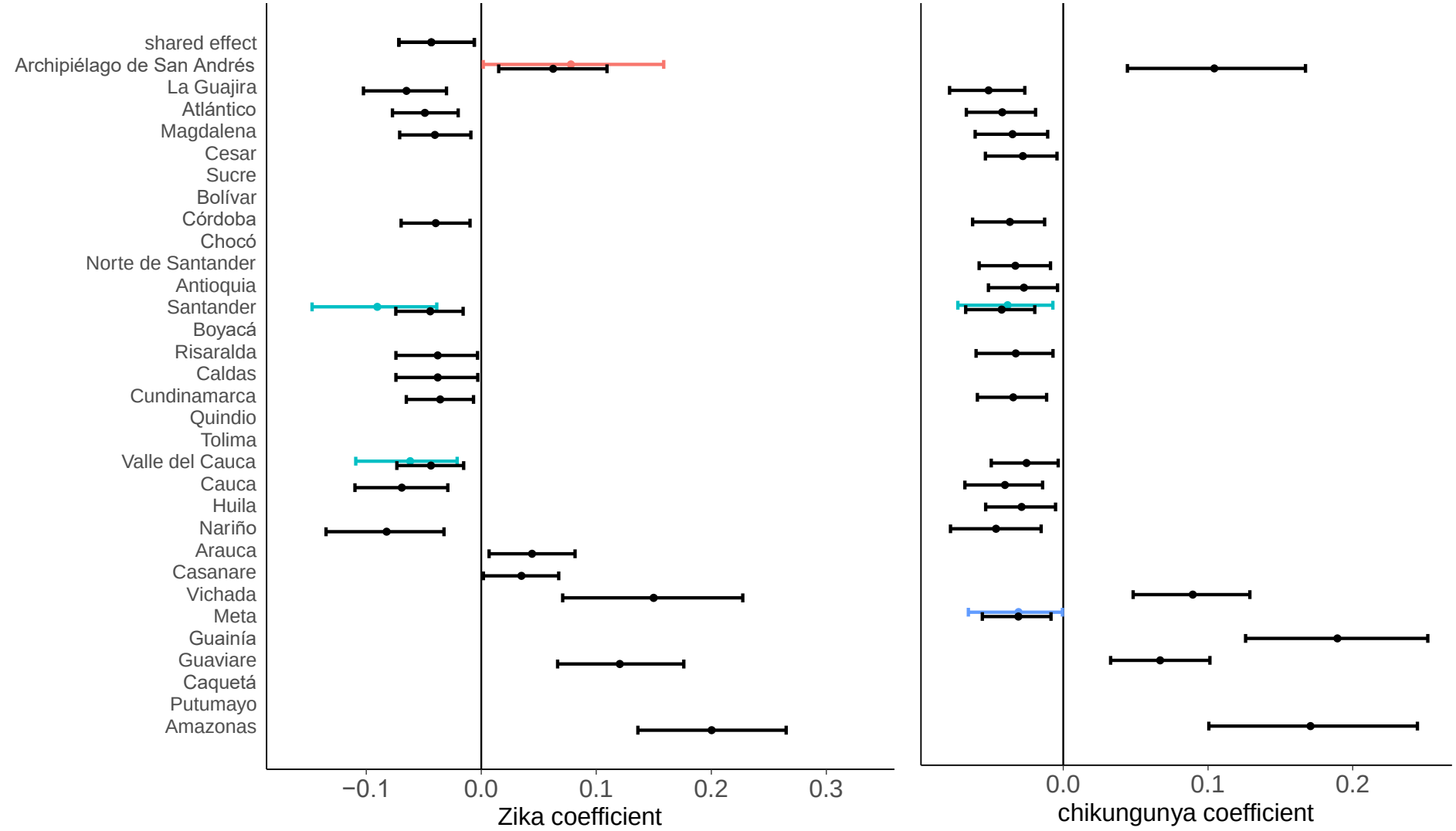
Trends of arboviral diseases, Colombia 2008-2017*



**** A semana epidemiológica 37 de 2017***

Fuente: Sivigila 2017. Instituto Nacional de Salud, equipo ETV Zoonosis.
Presentacion PAHO Octubre 2017.

ZIKV-CHIKV coefficients-Colombia



Future steps

Development and validation of models to explore:

- Characterize historical and recent transmission of arbovirus analyzing the time-series data that will allow to model possible future transmission scenarios.
- Establish if the emergence of Zika in Brazil might be related to recent changes in dengue dynamics (Cross-protection and/or enhancement).
- Test hypothesis about the possible relationship of yellow fever vaccine coverage and Zika severe outcomes so, if we can have access to YF vaccine coverage, we might also be able to test this.
- Other hypothesis

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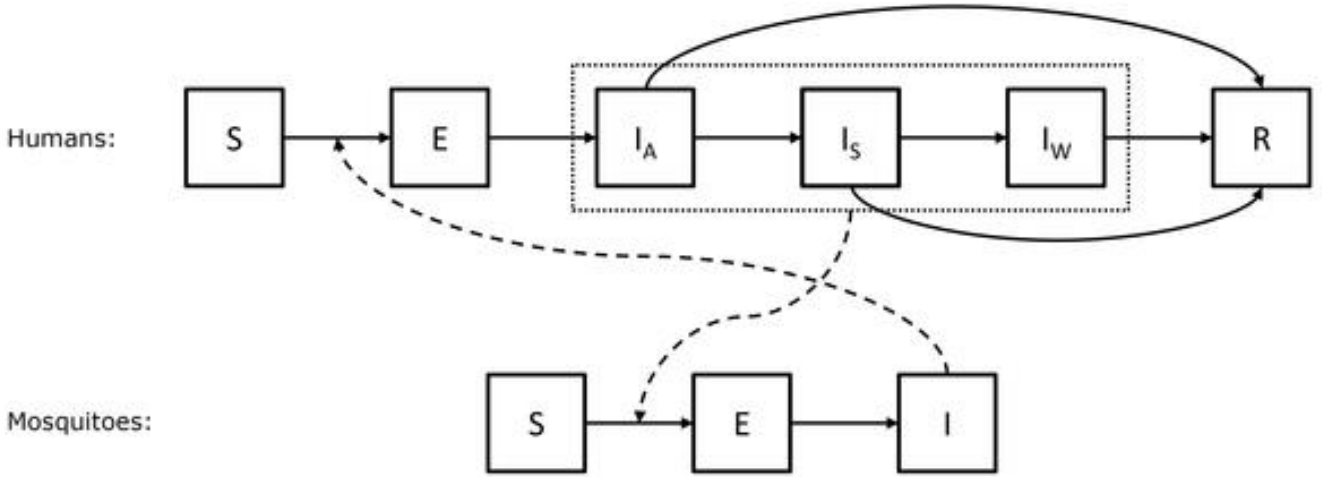
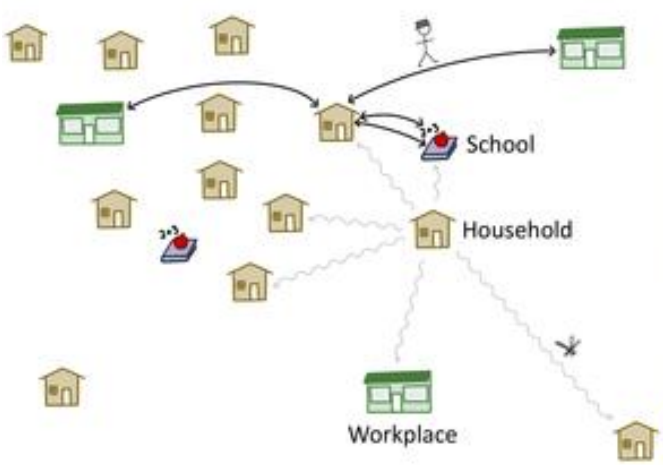
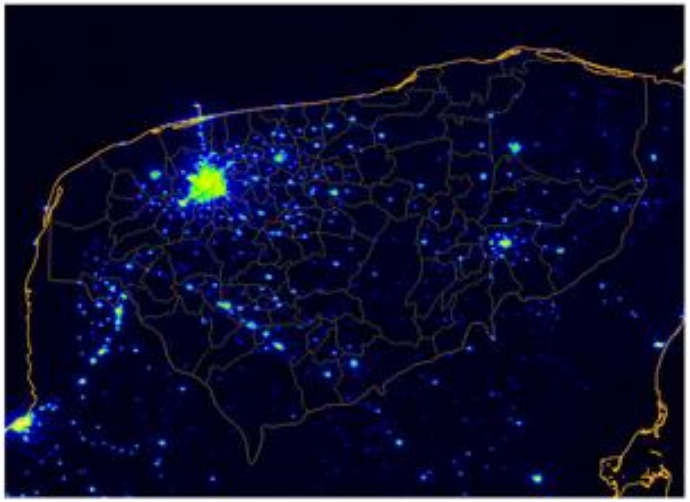
Projected Impact of Indoor Residual Spraying in Yucatán, Mexico

Hladish, T. J., Rojas, D. P., & Longini, I. M. (In Press) in *Plos Neglected Tropical Diseases*.

Epidemic and synthetic population model structures.

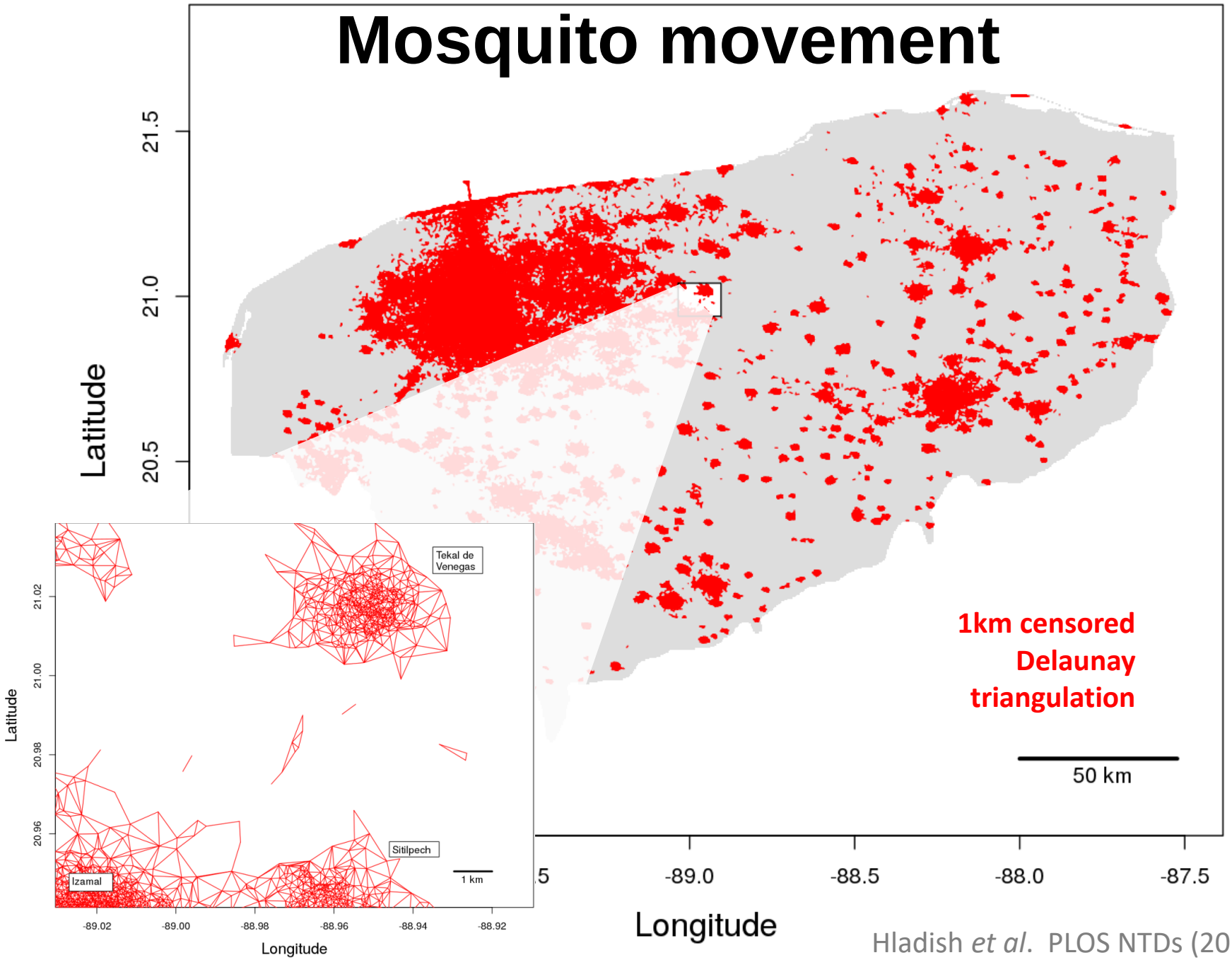






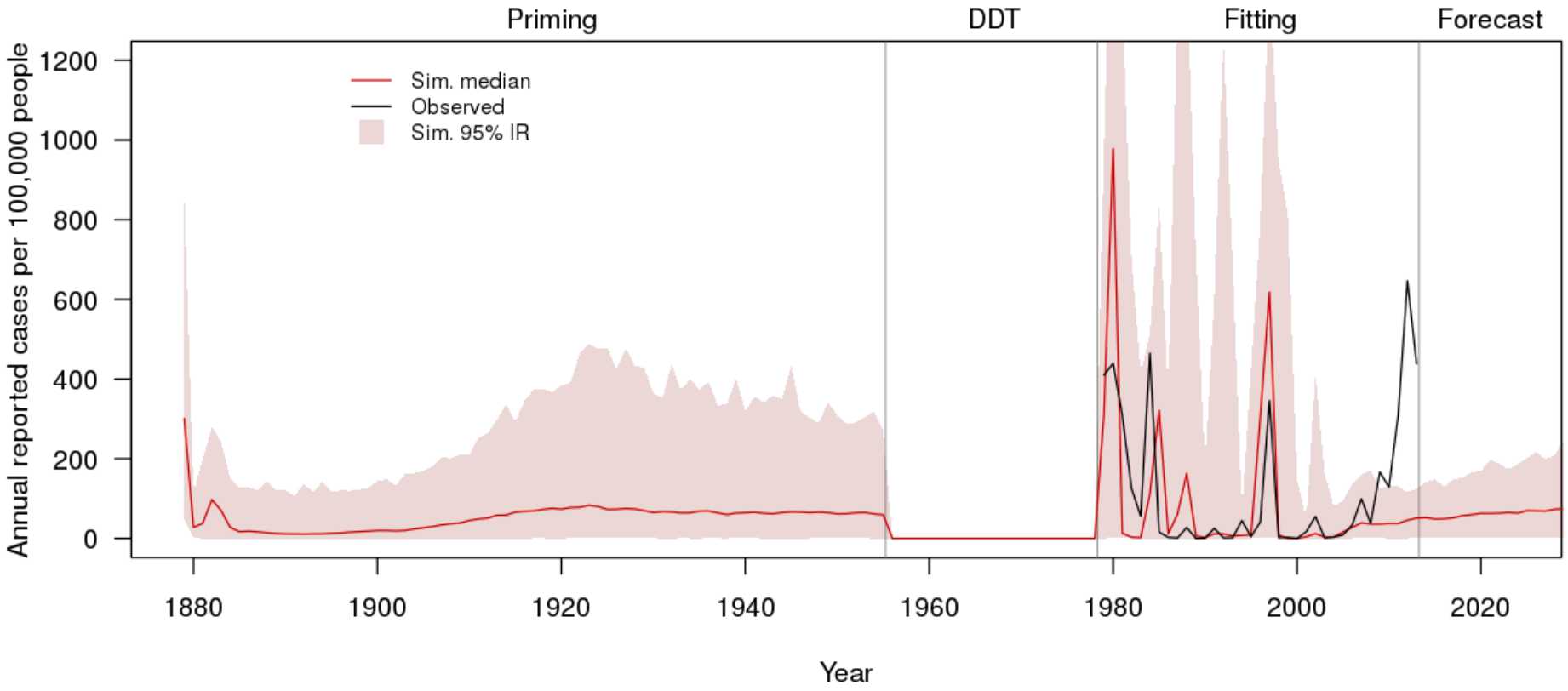
Hladish TJ, Pearson CAB, Chao DL, Rojas DP, Recchia GL, et al. (2016) Projected Impact of Dengue Vaccination in Yucatán, Mexico. PLOS Neglected Tropical Diseases 10(5): e0004661. https://doi.org/10.1371/journal.pntd.0004661
http://journals.plos.org/plosntds/article?id=10.1371/journal.pntd.0004661

Mosquito movement

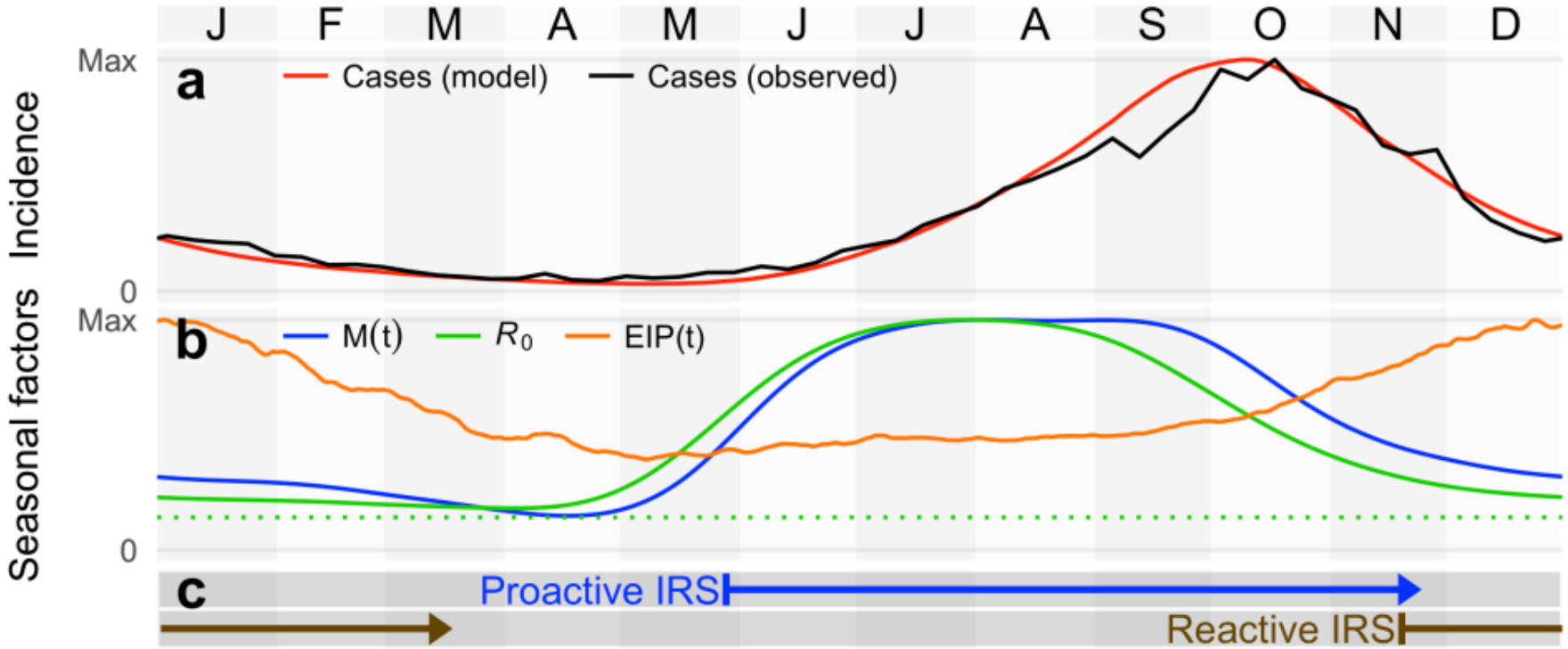


Hladish *et al*. PLOS NTDs (2016)

Reconstruct the past, forecast the future



Dengue seasonality in Yucatan, 1995-2015



Indoor residual spraying*

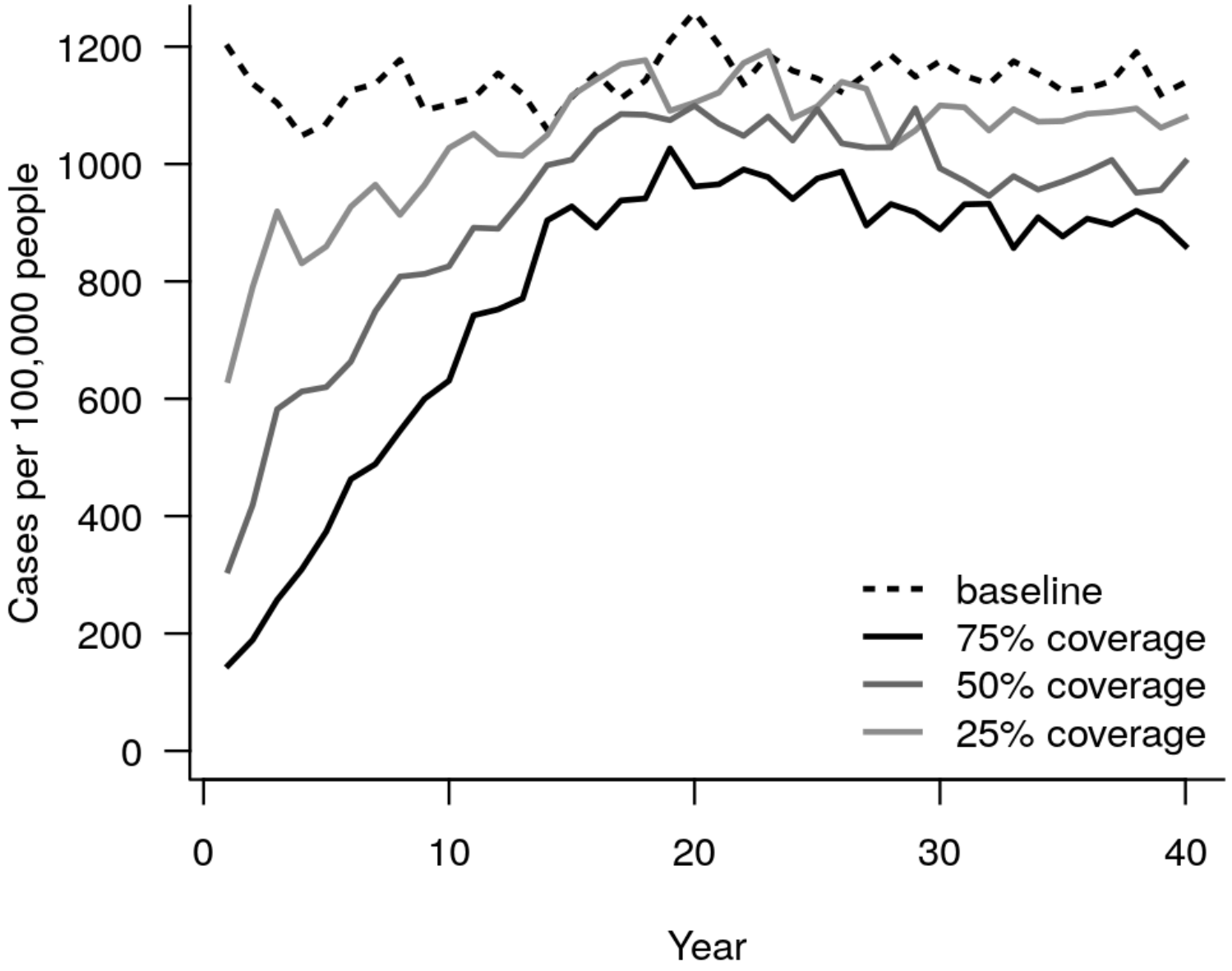
- Coverage: Treat 25/50/75% of houses per year
- Efficacy: 80% reduction in equilibrium pop size in treated houses
  - Corresponds to 13% daily mortality due to IRS
- Treatment lasts 90 days

Campaigns last 1/90/365 days

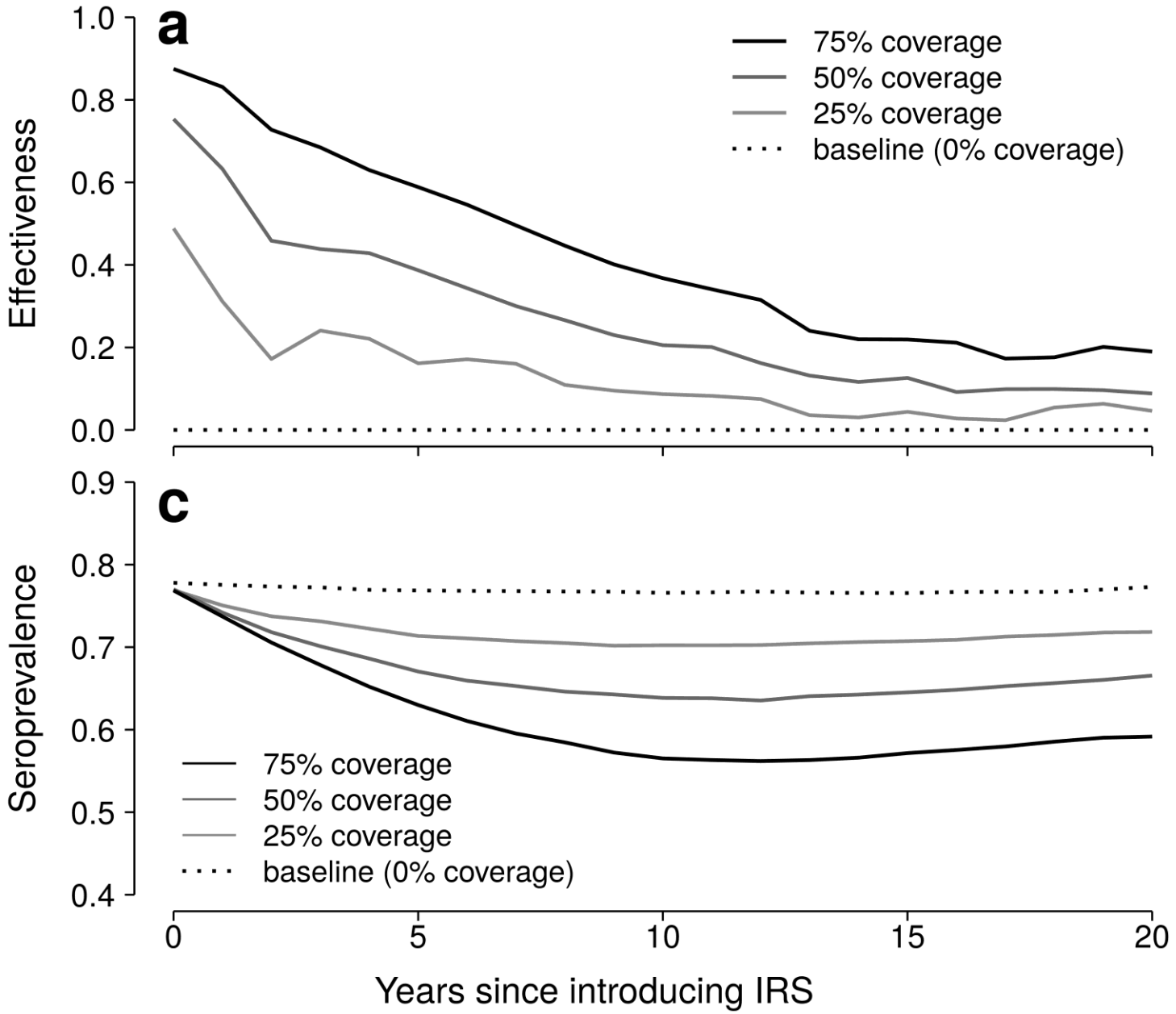
52 different start dates (1 and 90 day campaigns)

*Efficacy & durability based on Vazquez-Prokopec et al, *Science Advances* (2017)

Simulated impact of IRS (90-day campaign, 90-day durability, late May start)

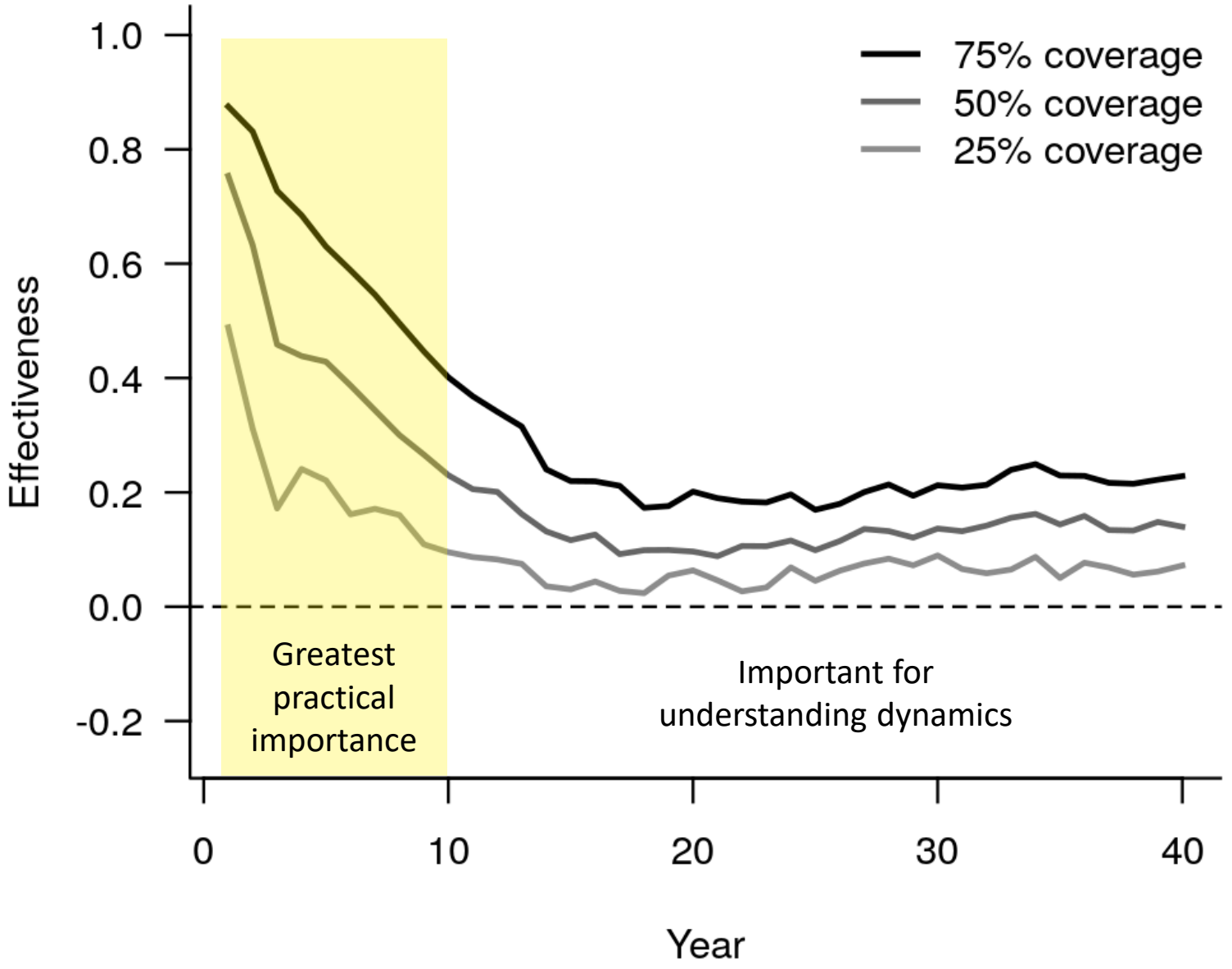


Population immunity drives long-term IRS effectiveness



Effectiveness decreases for 15 years, then levels out. Why?

(90-day campaign, 90-day durability, optimal timing: late May start)



Other applications of modeling on transmission dynamics of Arbovirus

Design cluster randomized trials for new technologies for vector control with epidemiological measures:

- Wolbachia
- Irradiated mosquitoes
- Dispersing stations of Pyriproxyfen
- Sterile mosquitoes to reduce the density of *Aedes aegypti*

Acknowledgments

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- Natalie Dean

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Northeastern University

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netsi Northeastern University Network Science Institute

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THANK YOU

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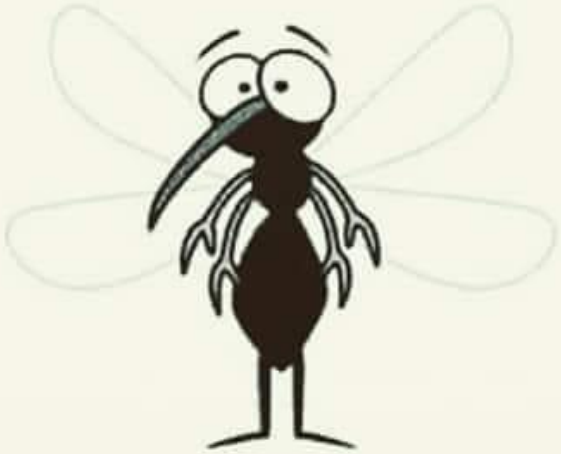
Cuanta **felicidad** habría en el mundo si en vez de sangre...



... ¡los mosquitos **chuparan grasa**!