University of Pittsburgh | Pitt Public Health

Forecasted size of measles outbreaks associated with vaccination exemptions for school children

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Overview

Measles

Agent-based models

Texas measles simulations

Results

Conclusions

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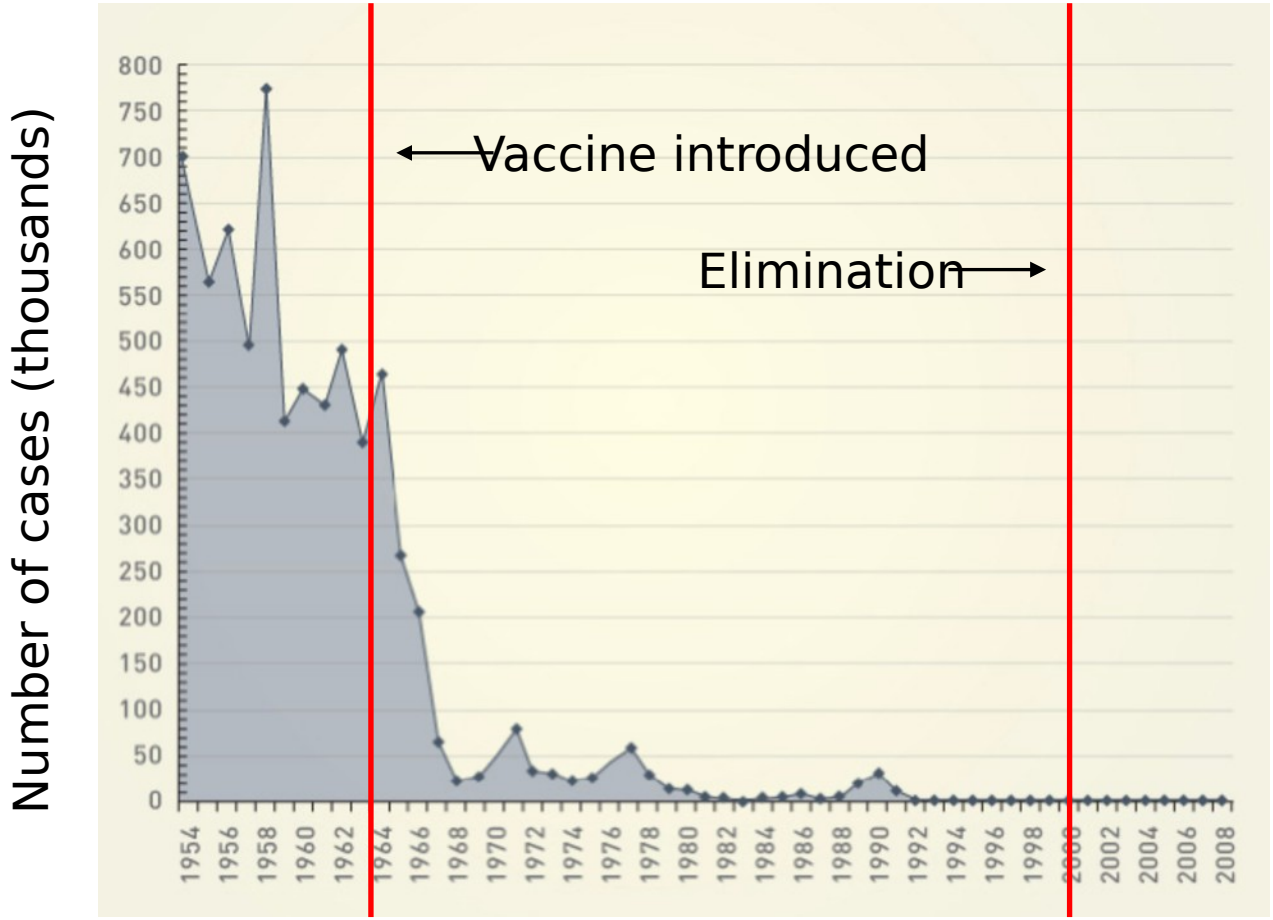
Measles

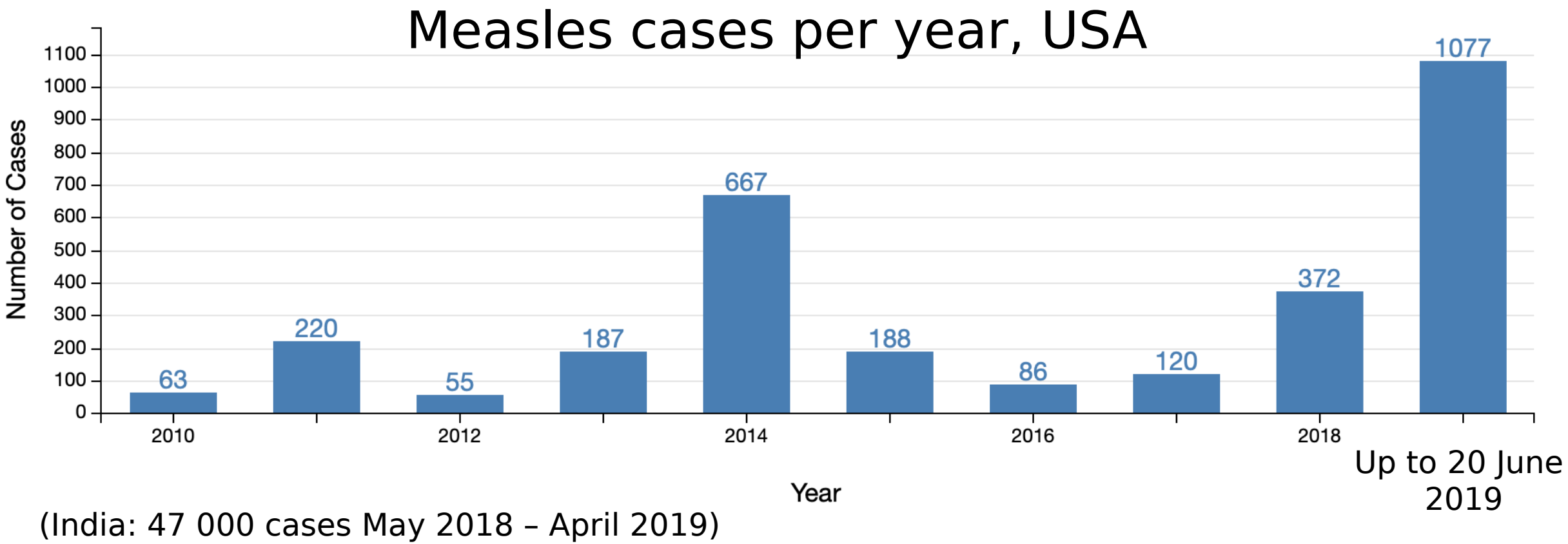
- Highly contagious
- Complications: pneumonia, brain damage, hearing loss, death
- MMR vaccine – 97% effective (2 doses)

Measles in the United States



Plot: historyofvaccines.or

Measles resurgent



(India: 47 000 cases May 2018 – April 2019)

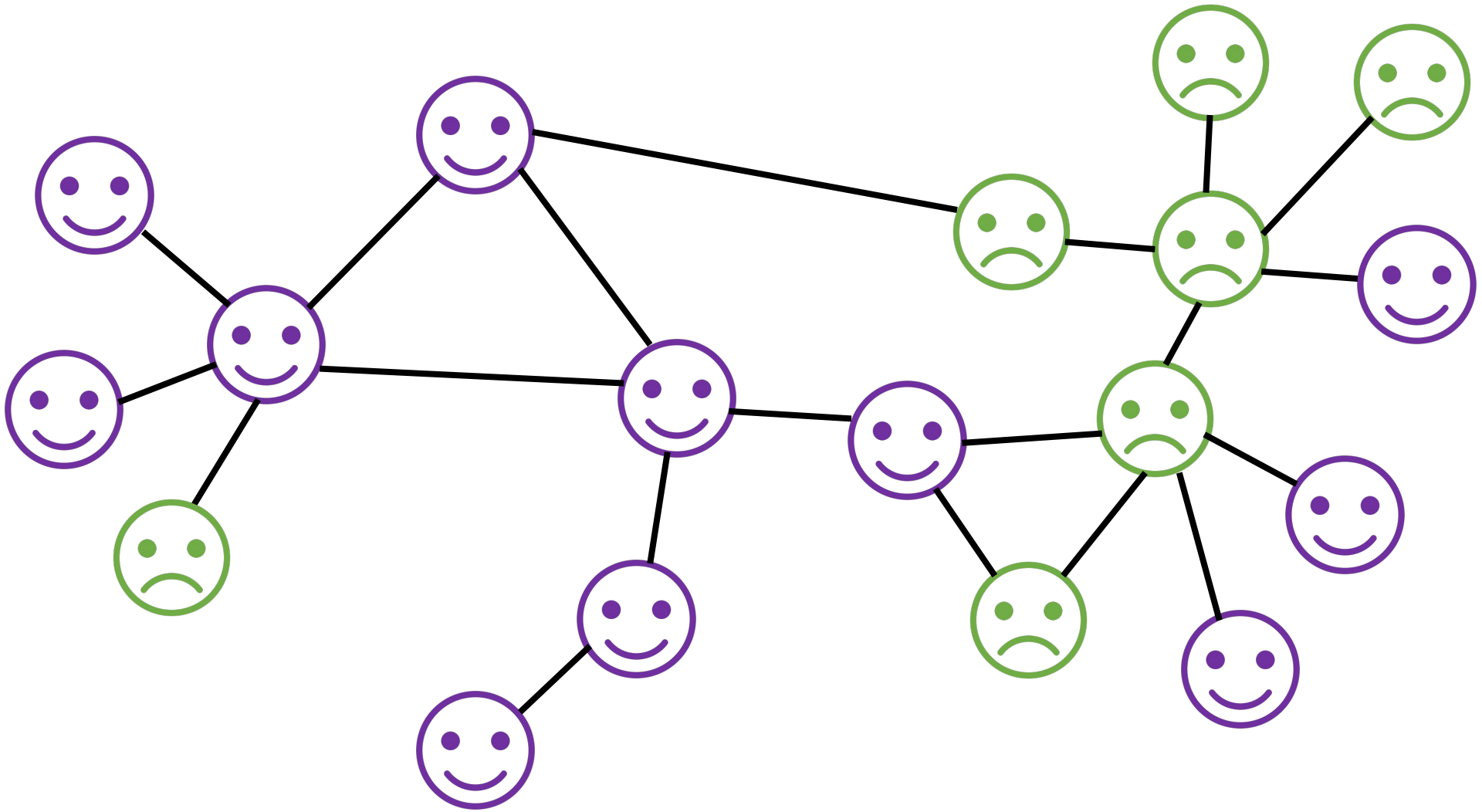
Vaccination requirements

- School students require vaccination
- or an exemption:
  - Medical
  - Personal
  - Religious

Vaccination exemptions

- Concerns of vaccine side-effects
- Low perceived susceptibility and severity of measles
- Social influences

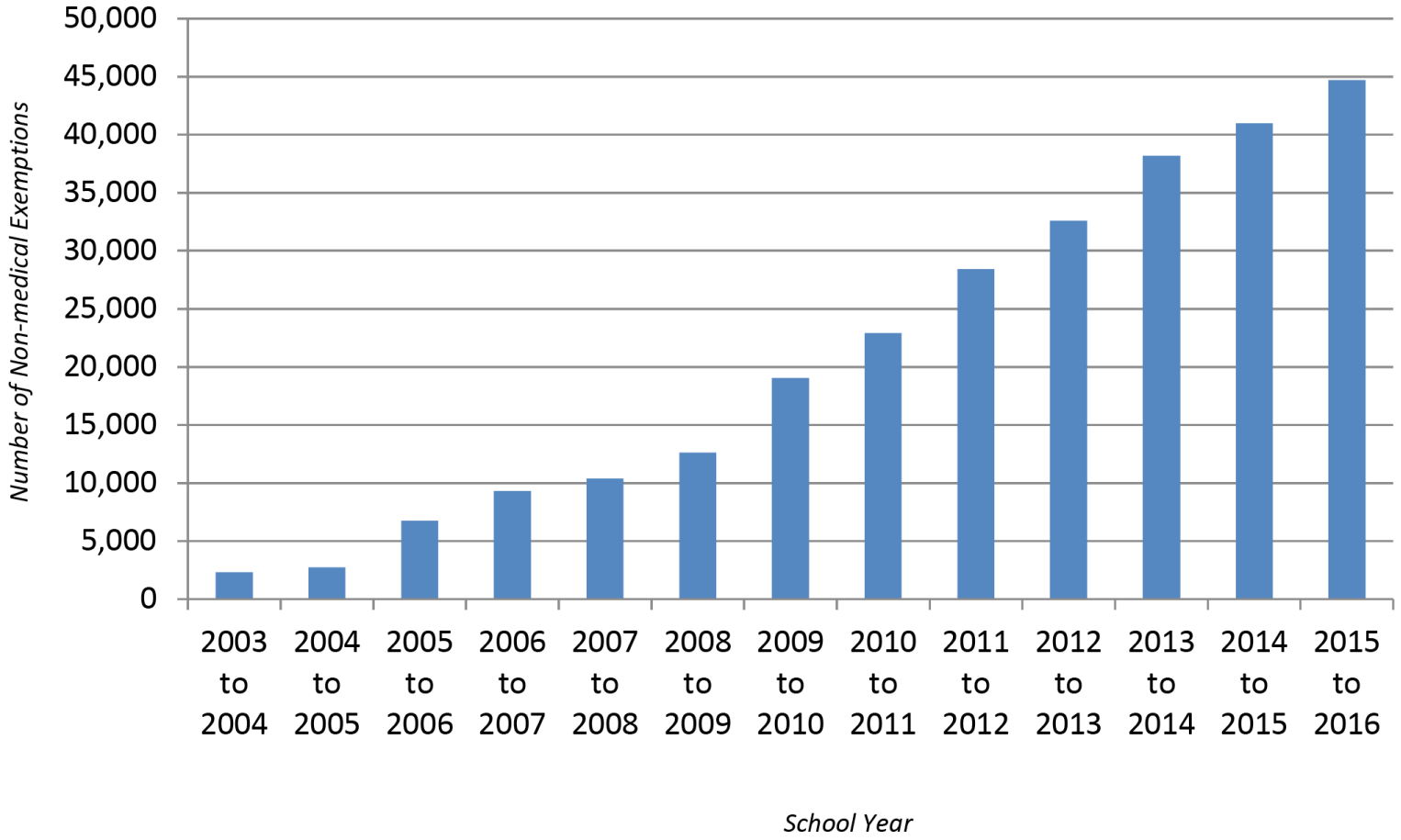
Clustering of vaccine hesitancy



Texas


Dallas
Houston
United States
Texas
Oklahoma
New Mexico
Arizona
Colorado
Kansas
Missouri
Louisiana
Arkansas
Mississippi
Tennessee
Kentucky
Illinois
Indiana
Ohio
Michigan
Wisconsin
Minnesota
Iowa
Nebraska
South Dakota
North Dakota
Montana
Wyoming
Idaho
Oregon
Nevada
Utah
California
Baja California
Sonora
Chihuahua
Coahuila
Nuevo León
Gulf of California
Gulf of Mexico
Florida
Georgia
North Carolina
South Carolina
Virginia
Pennsylvania
New York
Maine
Massachusetts
New Hampshire
Calgary
Regina
Winnipeg
Quebec City
Montreal
Ottawa
Toronto
Detroit
Chicago
Indianapolis
Washington
Kansas City
Nashville
Charlotte
Atlanta
Jacksonville
Orlando
Miami
New Orleans
Austin
San Antonio
El Paso
Dallas
Houston
Phoenix
Tucson
San Diego
Los Angeles
San Francisco
San Jose
Las Vegas
The Bahamas
Map data ©2019 Google

Texas: non-medical exemptions



Hotez PJ (2016) Texas and Its Measles Epidemics. PLoS Med 13(1

THE TEXAS TRIBUNE April 26, 2019

Some lawmakers want Texas to release vaccine opt-out rates for each school, not just for districts

OBSERVER March 21, 2018

Anti-Vaxxers are Claiming Victory After Texas Primaries. Will Their Influence Grow?

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Agent-based / Individual-based models

COMPRISES A COLLECTION OF AGENTS

AGENTS FOLLOW RULES

AGENT BEHAVIOR CAN ADAPT

BEHAVIOR AND INTERACTIONS OF AGENTS GENERATE POPULATION-LEVEL PHENOMENA

Agent-based / Individual-based models

Pros:

- Heterogeneous agents
- Agents have memory
- Spatial dependence

Cons:

- Parameterization
- Computationally intensive
- Learning curve

FRED

- **FRED** is a Framework for Reconstructing Epidemiological Dynamics

- **Framework:** FRED is not a model. FRED is a tool for building epidemiological agent-based models

Foundational Concepts in FRED

Agent

Individual person

Space

Three-dimensional geography based on actual locations

Time

Time step = 1 hour (agents have multiple serial activities per day)

Duration = 1 day to 100 years

Places (mixing groups for agents)

Households, neighborhoods, workplaces, schools

Flexibly create additional places

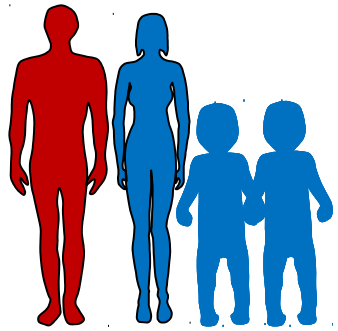
Population

Based on census data and other sources

Agents are associated with specific places

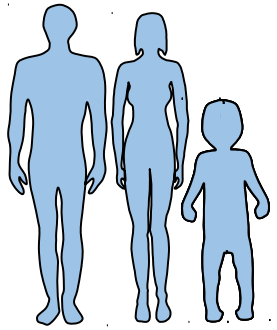
FRED Daily Dynamics

Location and size
of each school

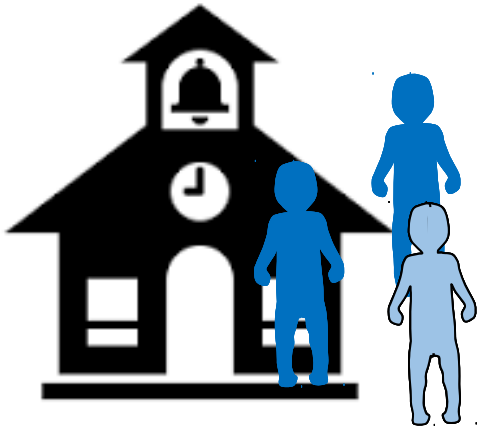


Household size,
ethnicity, ages,
income

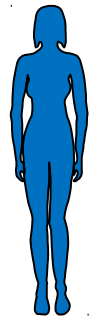
Location and size
of each workplace



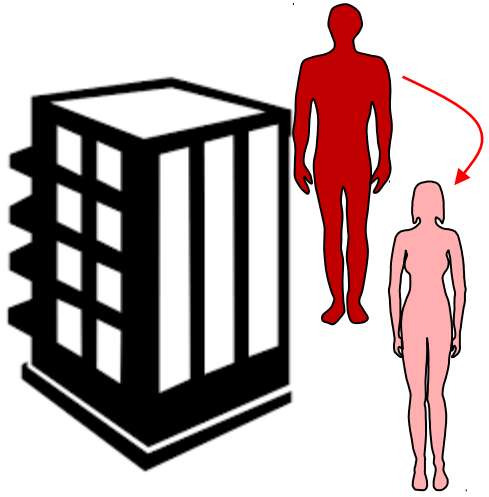
FRED Daily Dynamics



Location and size
of each school



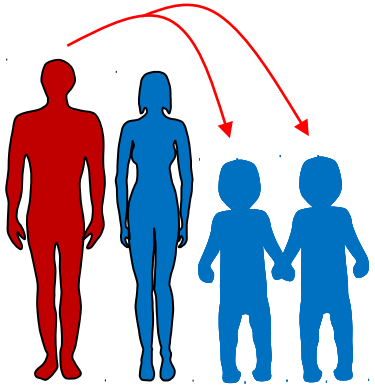
Household size,
ethnicity, ages,
income



Location and size
of each workplace

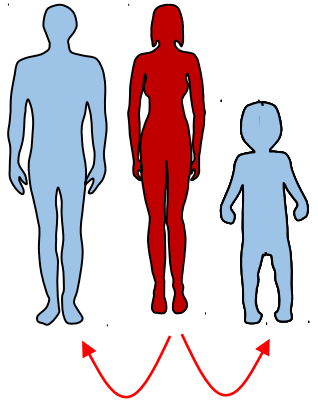
FRED Daily Dynamics

Location and size
of each school



Household size,
ethnicity, ages,
income

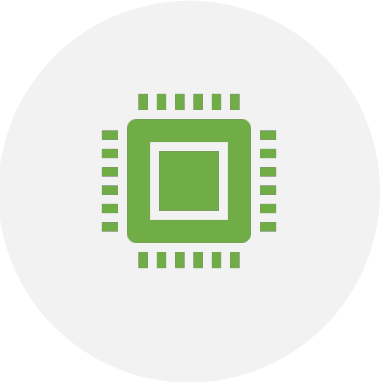
Location and size
of each workplace



FRED

BARRIERS TO USE

LEARNING CURVE



COMPUTING RESOURCES

FRED Web

Online platform for creating, running & analyzing agent-based models in FRED

Graphical User Interface

Simulations run on dedicated server

Plotting and mapping tools for data analysis

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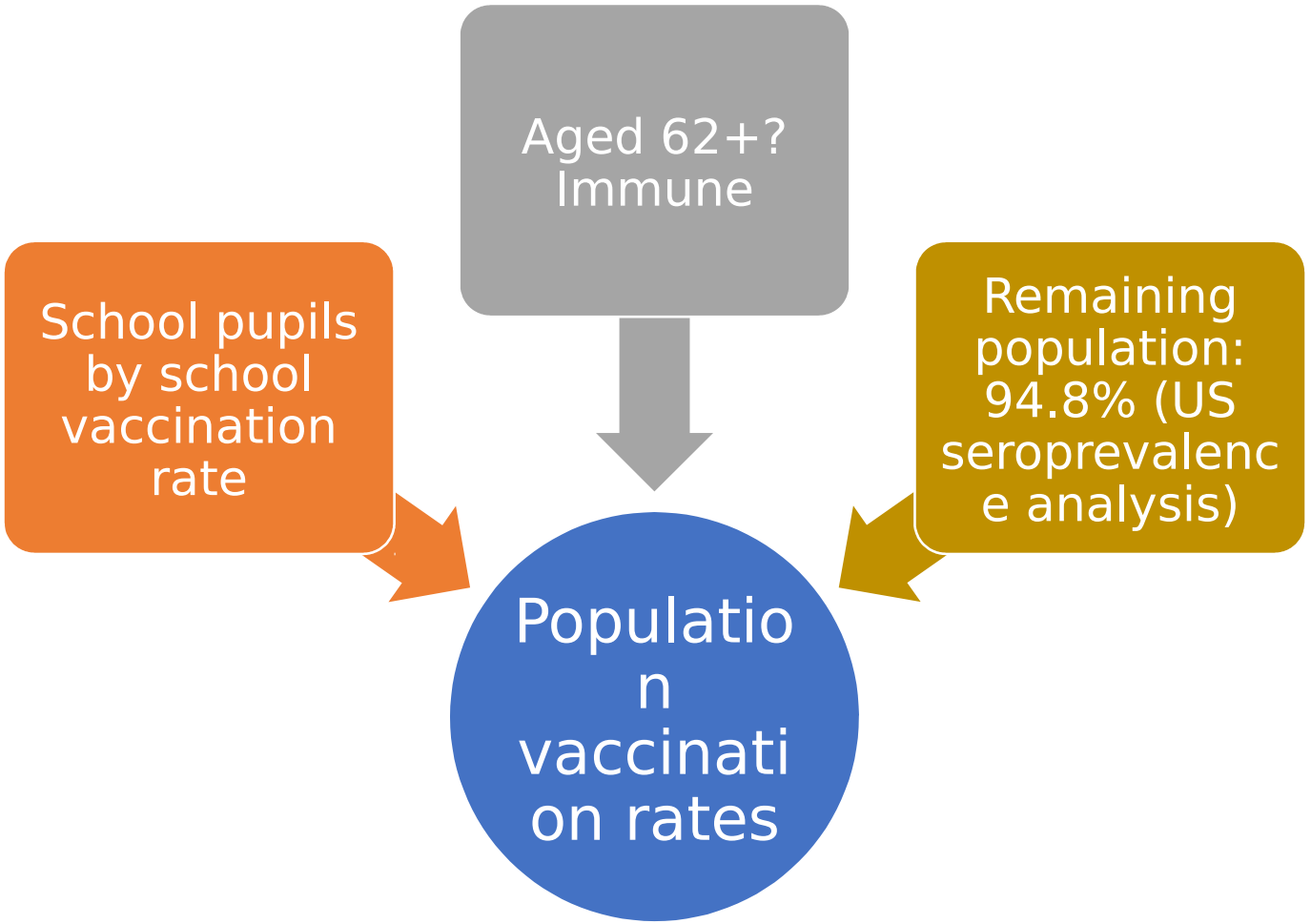
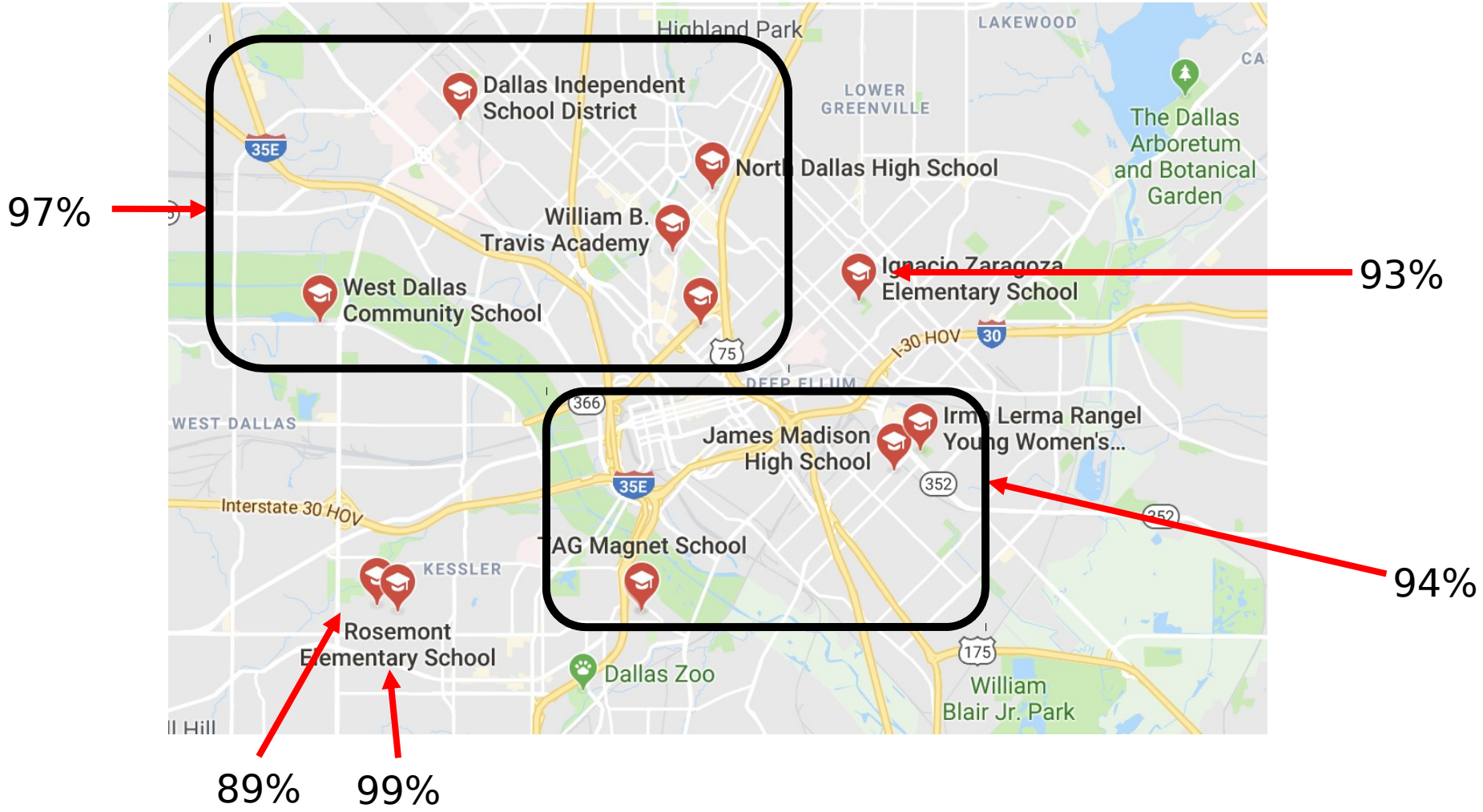
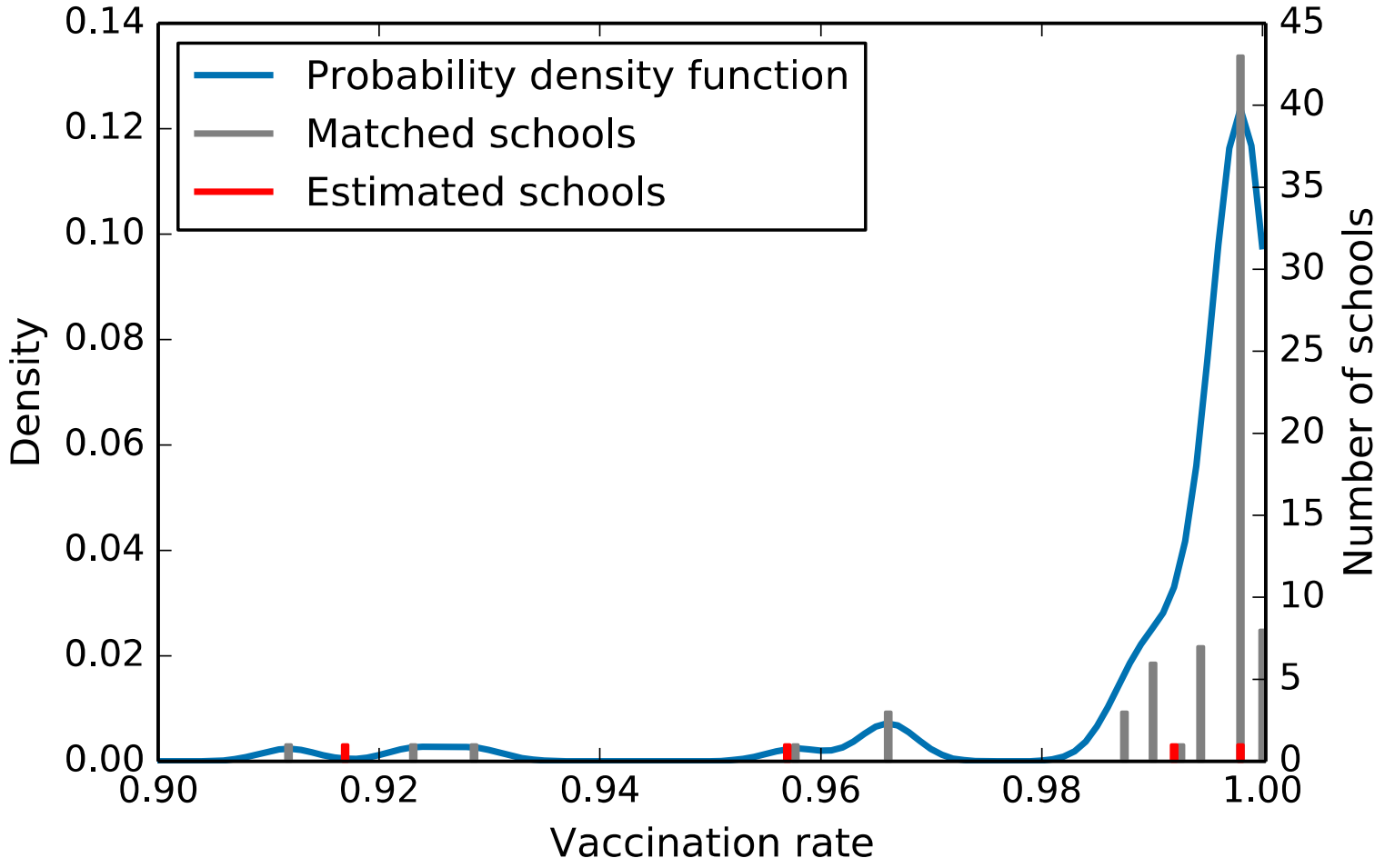
Vaccinate population



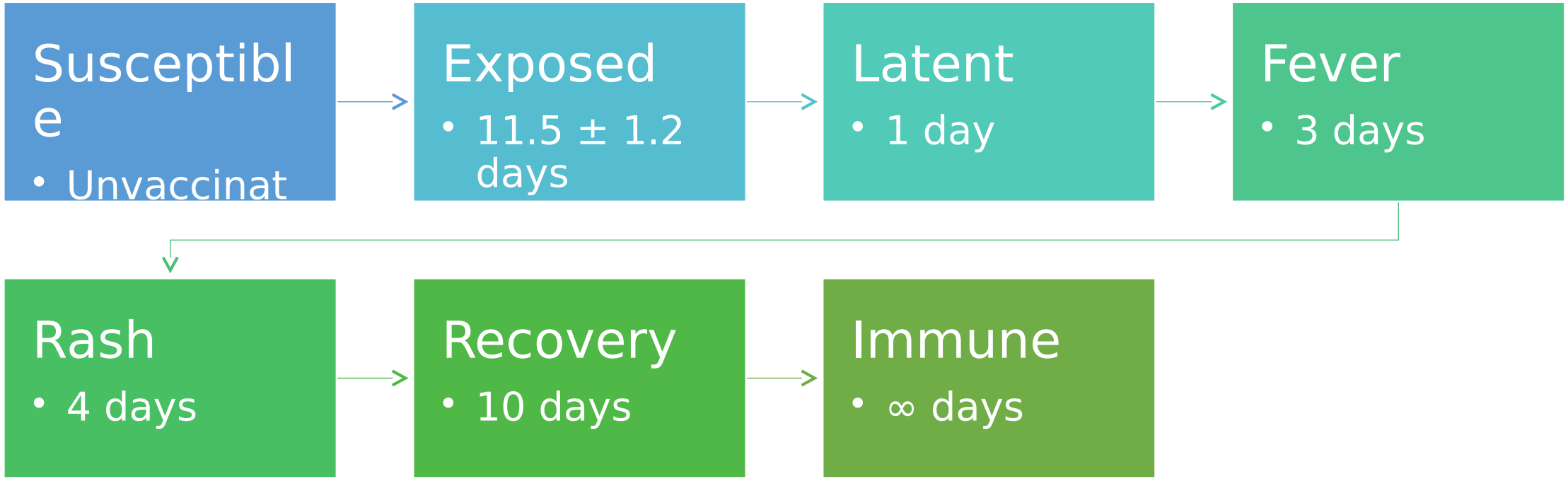
Assign vaccination rates to schools



Missing schools



Measles state model



Epidemiology and Prevention of Vaccine-Preventable Diseases, Centers for Disease Control and Prever

Simulations

Infect one randomly pupil with non-medical exemption

Count cases for 9 simulated months

No interventions

Simulate each metropolitan area in Texas

Current and decreased vaccination rates

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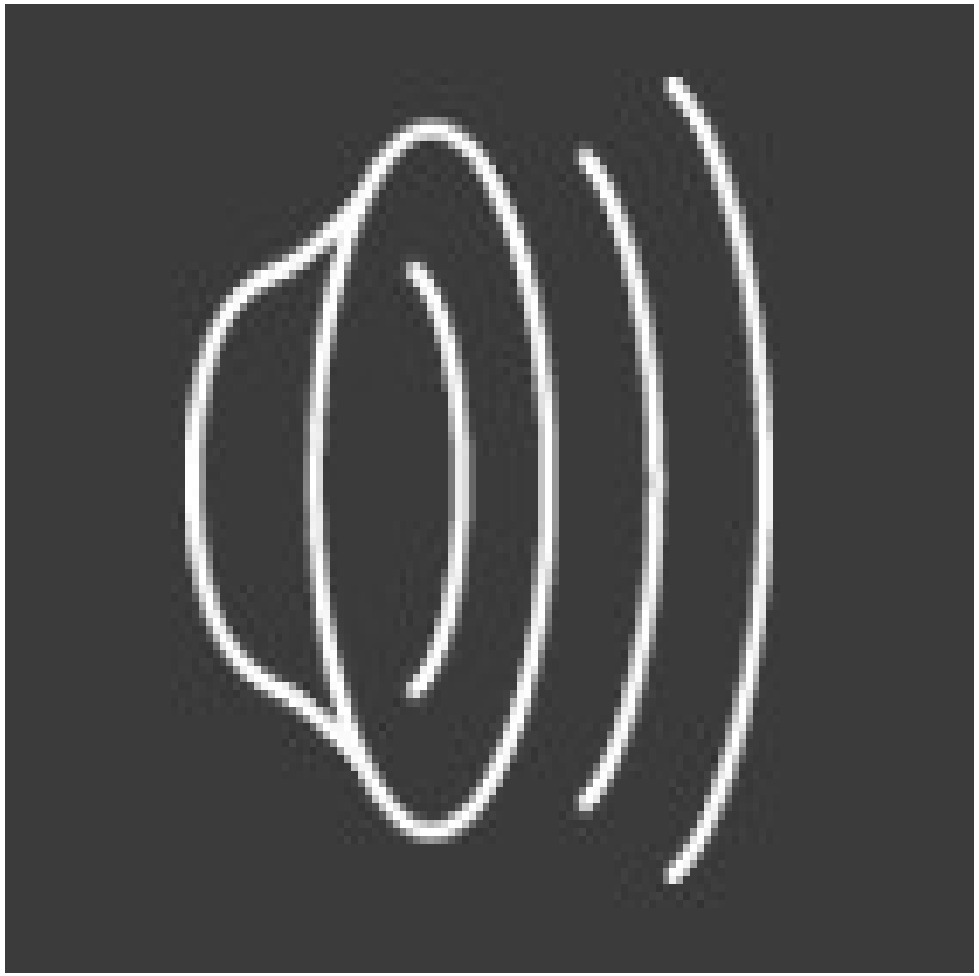
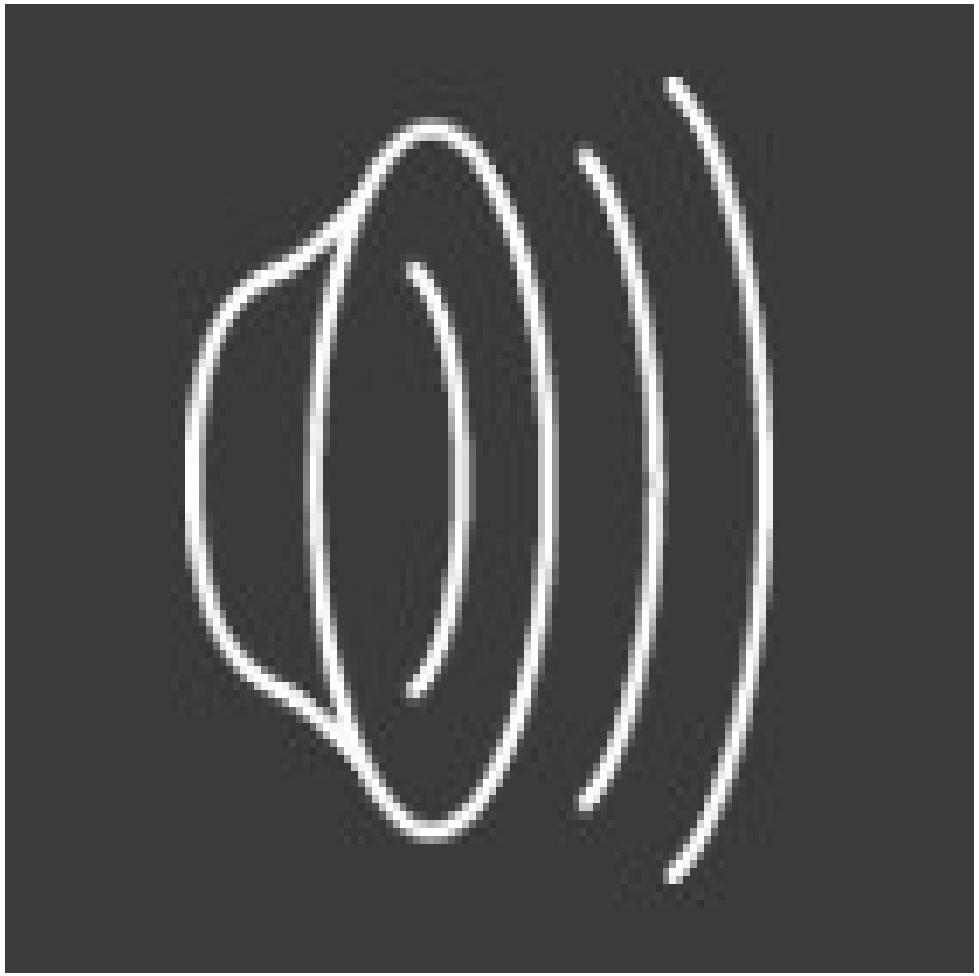
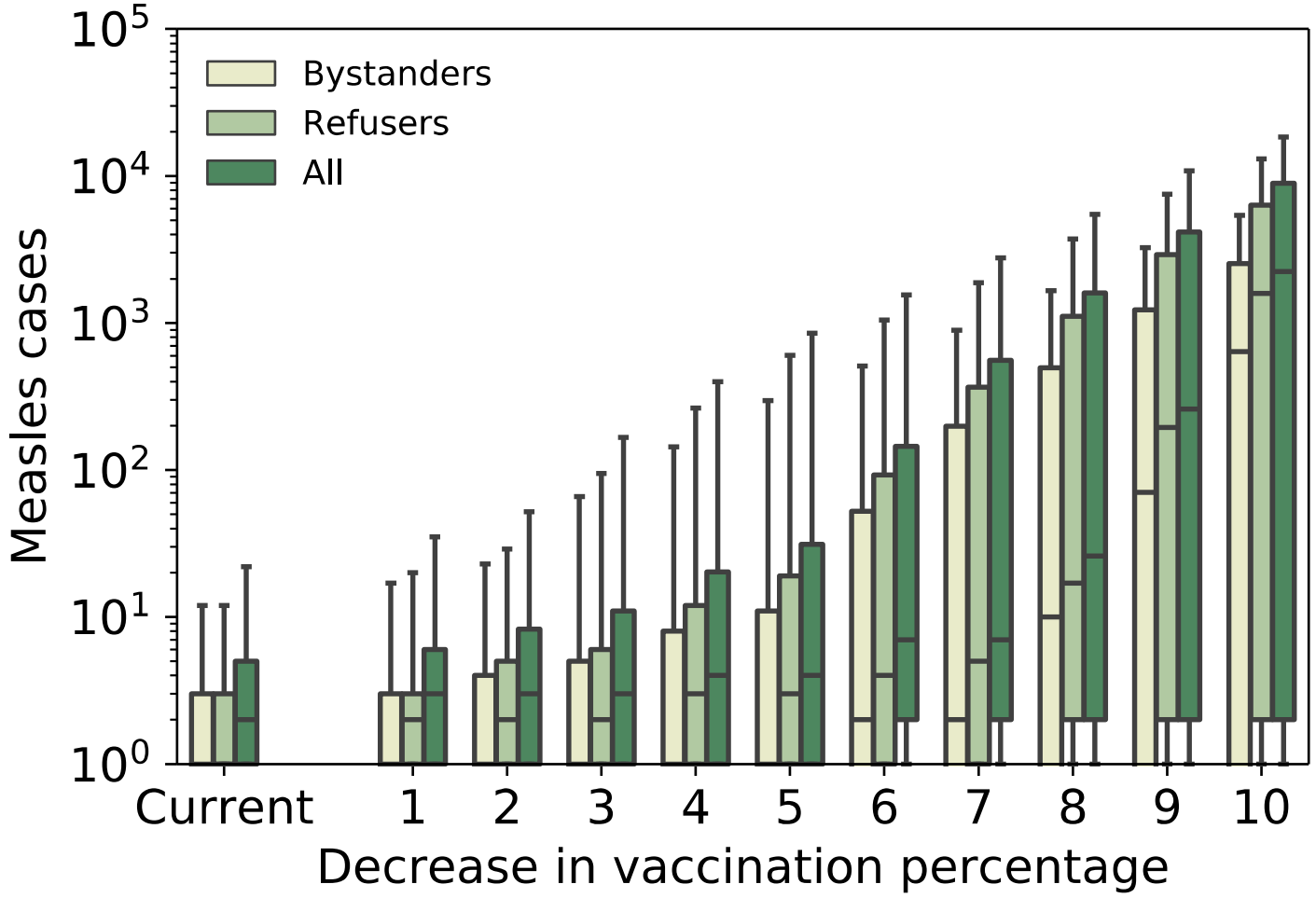
Austin simulations





Houston forecasts



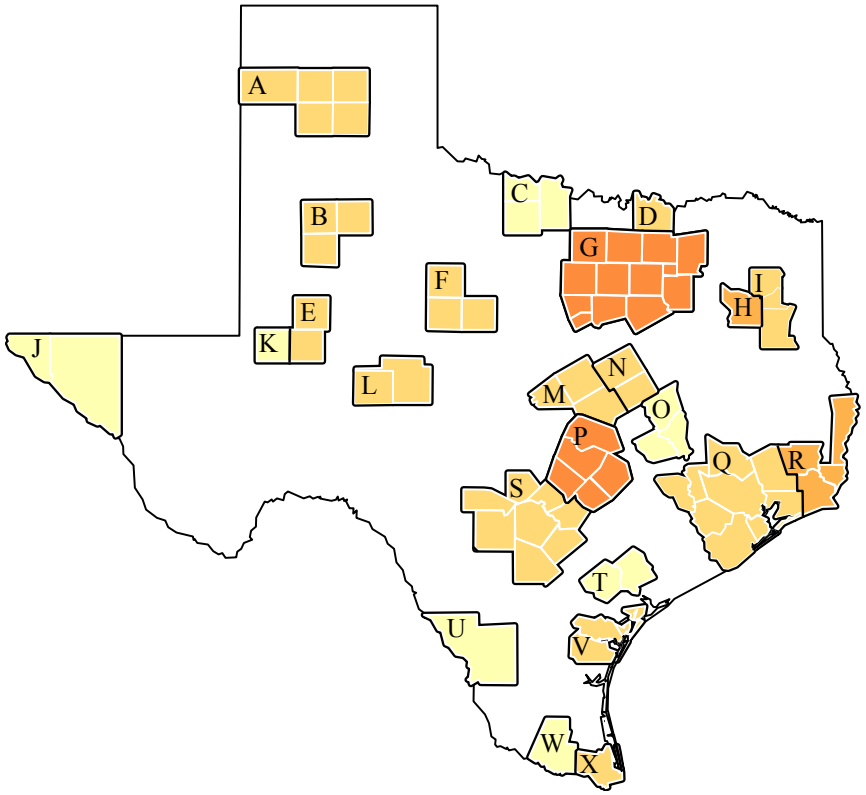
in bystanders

when cases >25

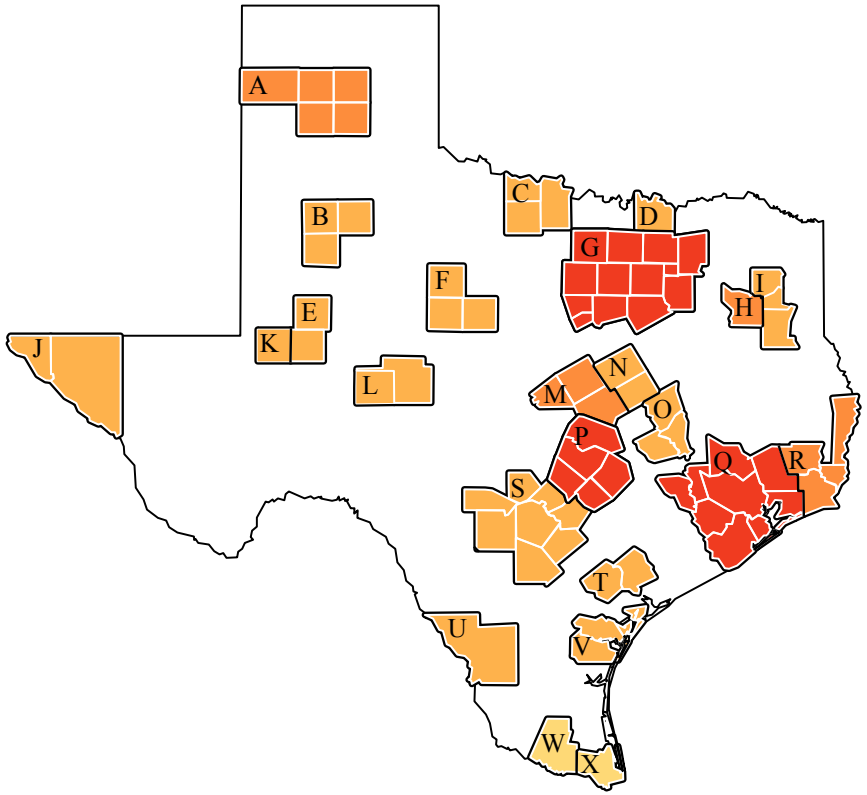
Bystanders:

- Vaccine failed
- Medical exemption
- Unvaccinated adults

Forecasts mapped



2018 vaccination rates



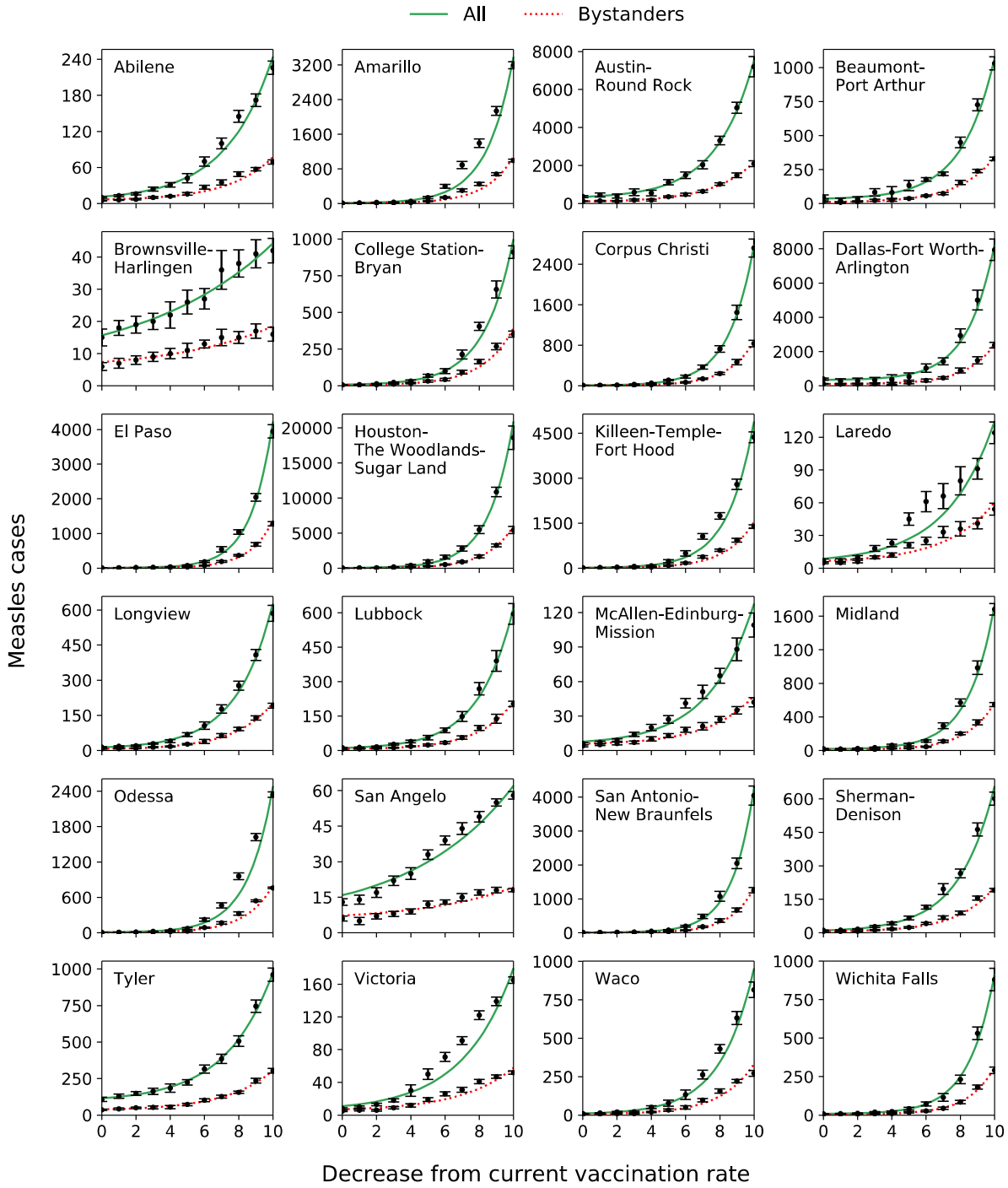
2018 -5% vaccination rates

Measles cases

- > 512
- 128 - 512
- 32 - 128
- 8 - 32
- < 8

A - Amarillo
B - Lubbock
C - Wichita Falls
D - Sherman-Denison
E - Midland
F - Abilene
G - Dallas-Fort Worth-Arlington
H - Tyler
I - Longview
J - El Paso
K - Odessa
L - San Angelo
M - Killeen-Temple-Fort Hood
N - Waco
O - College Station-Bryan
P - Austin-Round Rock
Q - Houston-The Woodlands-Sugar Land
R - Beaumont-Port Arthur
S - San Antonio
T - Victoria
U - Laredo
V - Corpus Christi
W- McAllen-Edinburg-Mission
X - Brownsville-Harlingen

All metro areas



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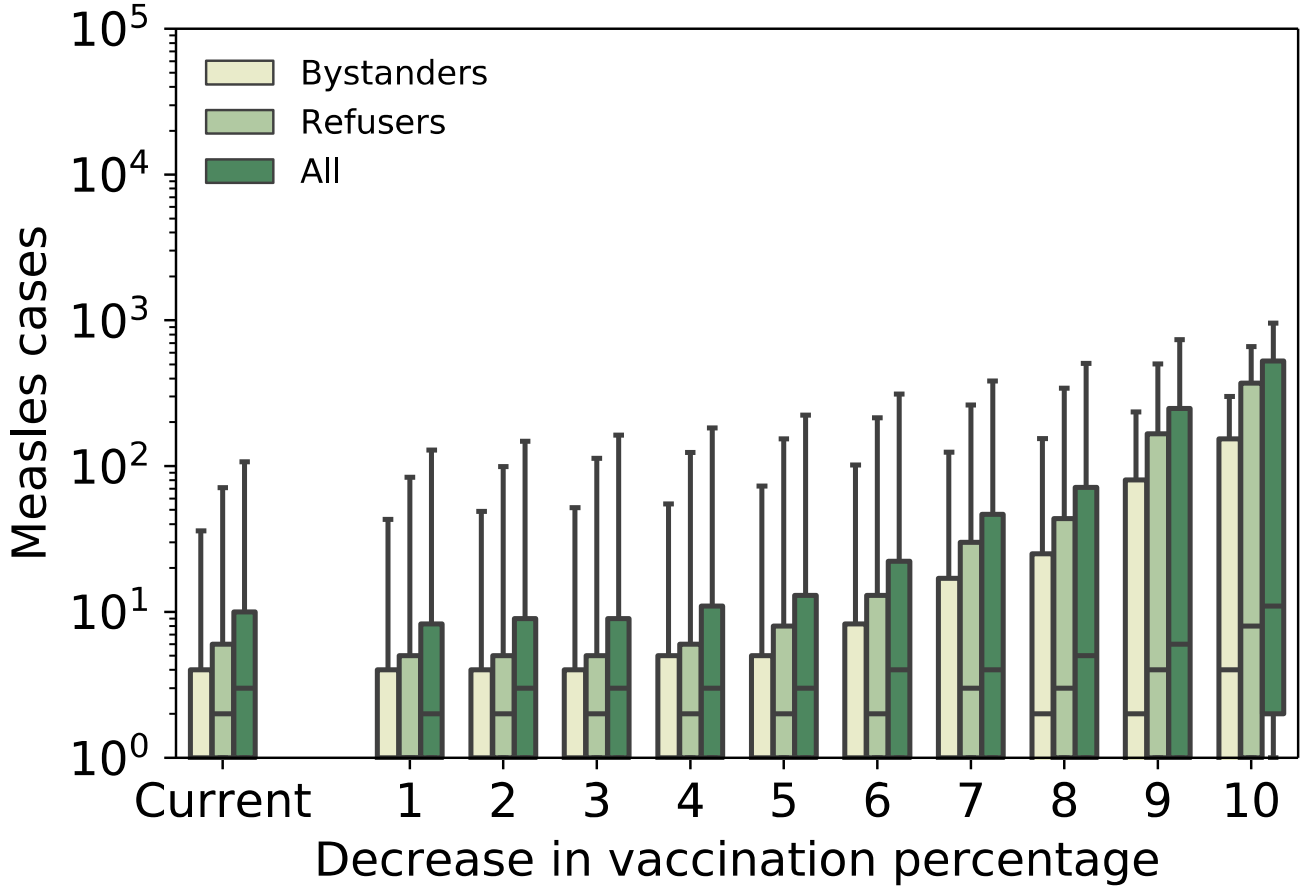
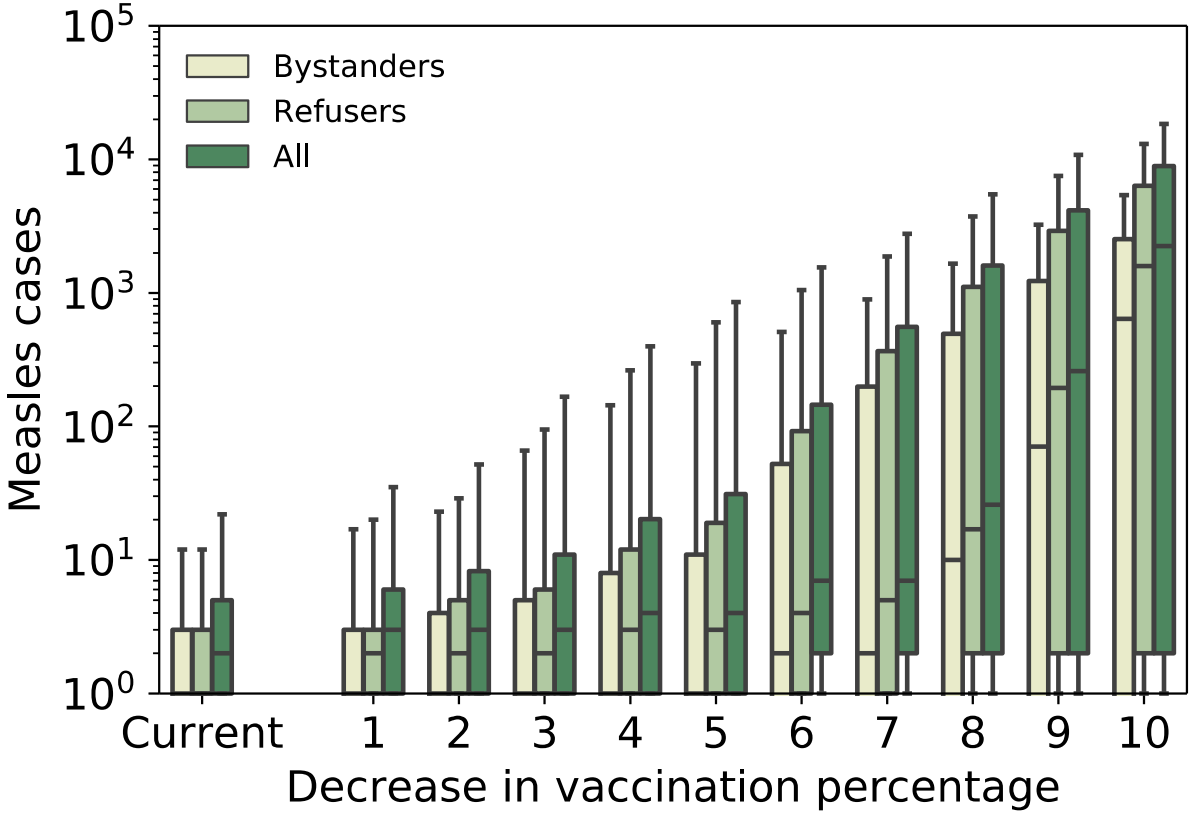
Geographic clustering

Tyler
210,000 people
Outbreaks >100 now
Two schools: 70% and 85% vaccinated

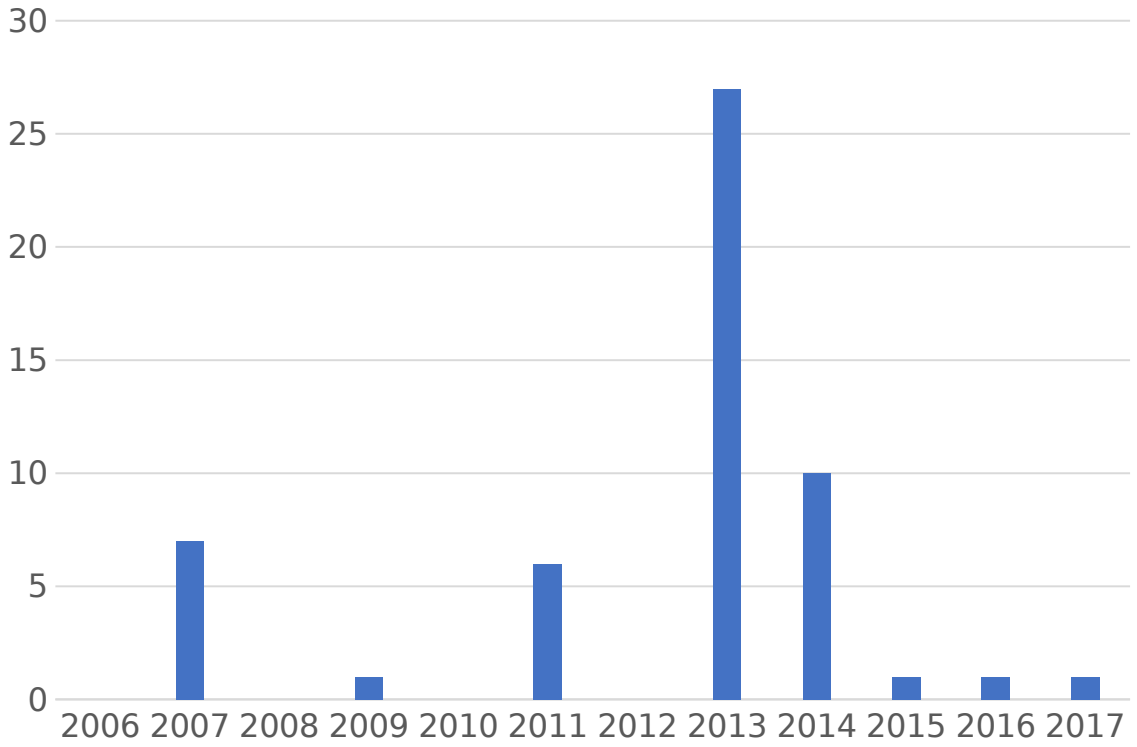


Small outbreaks – false security?

Simulation forecast (Houston)



Annual reported cases (Texas)



Personalize risks

VACCINE EFFICACY AND SAFETY WELL-ESTABLISHED

YET VACCINE HESITANCY GROWING

PERSONALISING FORECASTS MIGHT HELP?

FRED Impact

"... Sen. Marty Block, a San Diego Democrat, said he was convinced to vote “yes” after Pan showed him a computer modeling program [Link to FRED] from the University of Pittsburgh that simulates how quickly a measles outbreak could spread depending on a community's vaccination rate."

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AP

California, 11 other states introduce vaccine bills

By Andis Robeznieks | April 22, 2015

Health officials have declared California's measles outbreak over, but the legislative response is just getting rolling.

The outbreak started at the Disneyland theme park and sickened 131 Californians and another 16 people from other states.

Conclusions

- Significant chance >400 cases in a measles outbreak in Texas now
- Continued reduction in vaccination rates may exponentially increase outbreak sizes
- ≥ 1 cases in bystanders
- Personalising risks can help reduce vaccine hesitancy