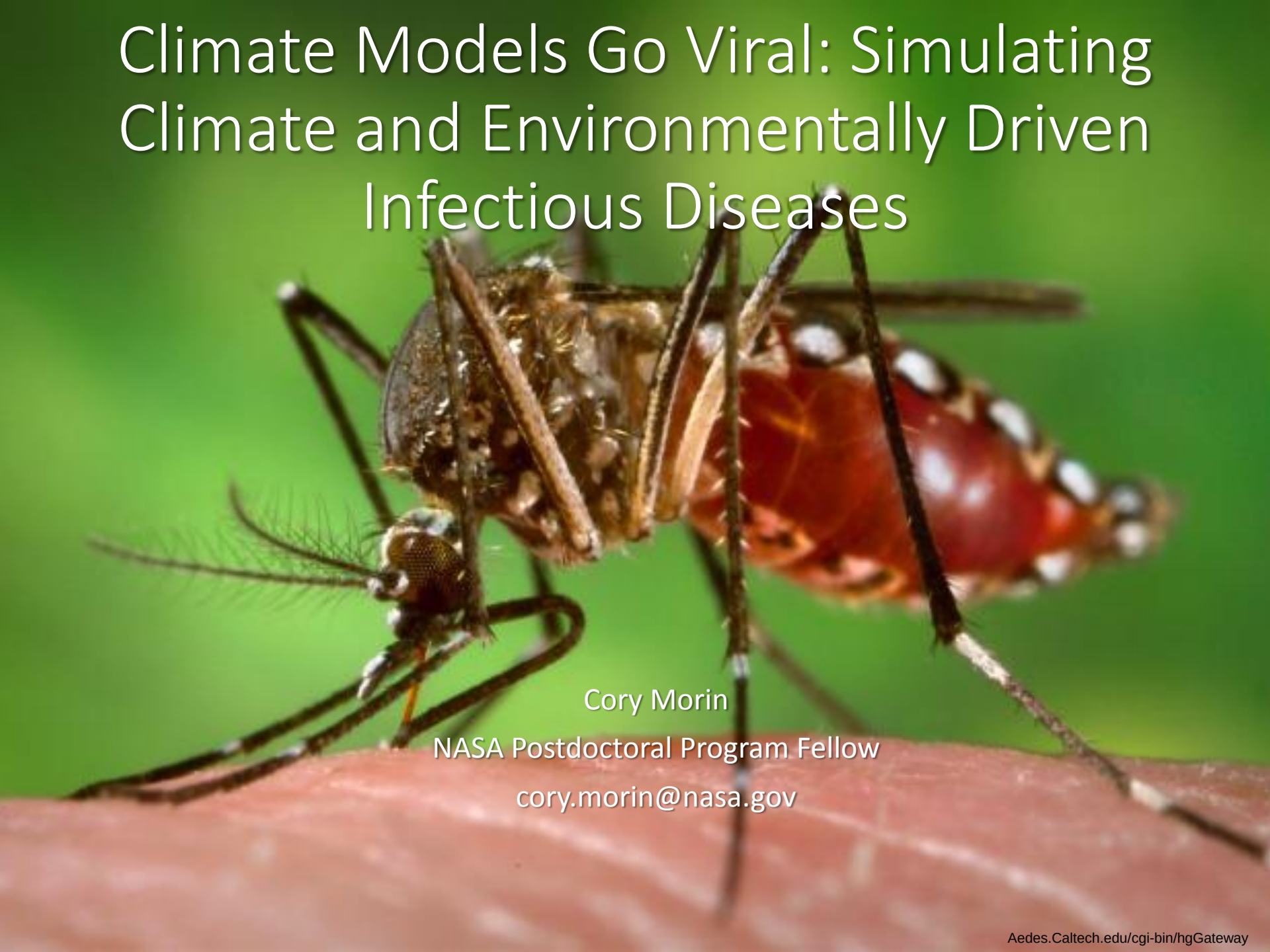
Climate Models Go Viral: Simulating Climate and Environmentally Driven Infectious Diseases



Cory Morin

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Aedes.Caltech.edu/cgi-bin/hgGateway

Media Panic!

DAILY NATION

The newspaper that serves the nation

Panic as 1,500 die of malaria

Epidemic killing 45 a day in Wajir

INSIDE

Issues behind the violence in Rift Valley

Kenya for diplomacy in Iraq issue

Kabila snubs Jesse Jackson

http://www.explorelifeonearth.org/headline.jpg

PANIC OVER KILLER VIRUS

EBOLA: WORLD GOES ON RED ALERT

» Hunt for dozens of jet 'victims' » Docs prepare for UK outbreak

ALL NEW!
• SHOCKING!
• BIZARRE!
• INCREDIBLE!!!
and it's ALL TRUE!

WEEKLY WORLD NEWS

THE WORLD'S ONLY RELIABLE NEWSPAPER

THE 11th PLAGUE!

BIRD FLU PANIC!

How you could protect your health & wealth from the coming epidemic

Download your FREE copy today!

Scientists claim a bird-flu epidemic is a certainty ... with up to a quarter of the UK population dying in less than 18 months ... collapsing the health service and the economy.

New this report reveals exactly how you could protect your health ...

• Including easily available natural remedies that out-perform anti-viral drugs in medical trials.

PLUS how you could make serious short-term money from the Bird Flu hype in the media ...

• Including UK companies you could invest in for potential profit if "pandemic panic" worsens.

Download your FREE copy NOW at:
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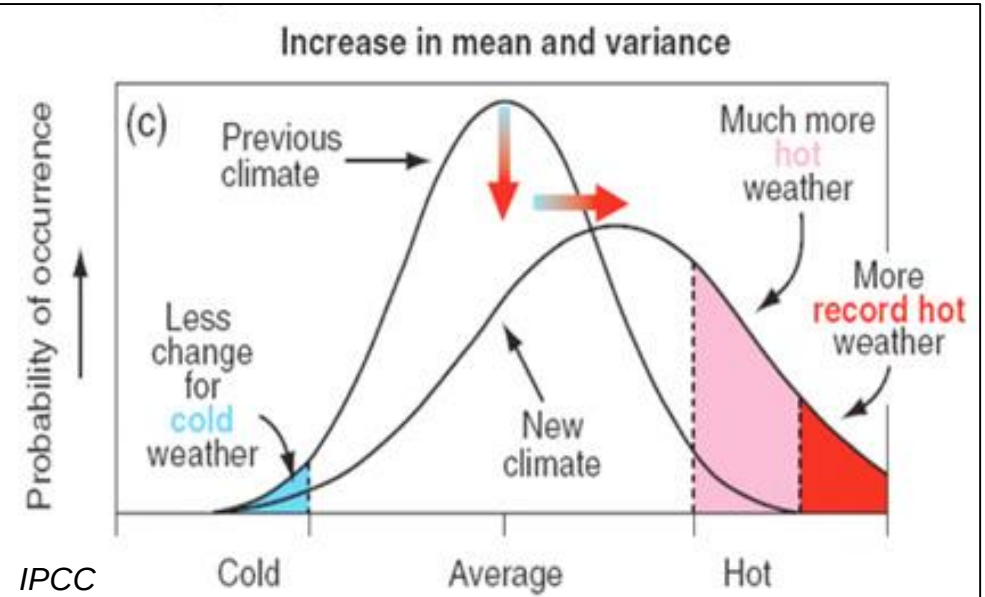
Linsay Lohan Stricken with Rare, Incurable Disease!

Outline of Presentation

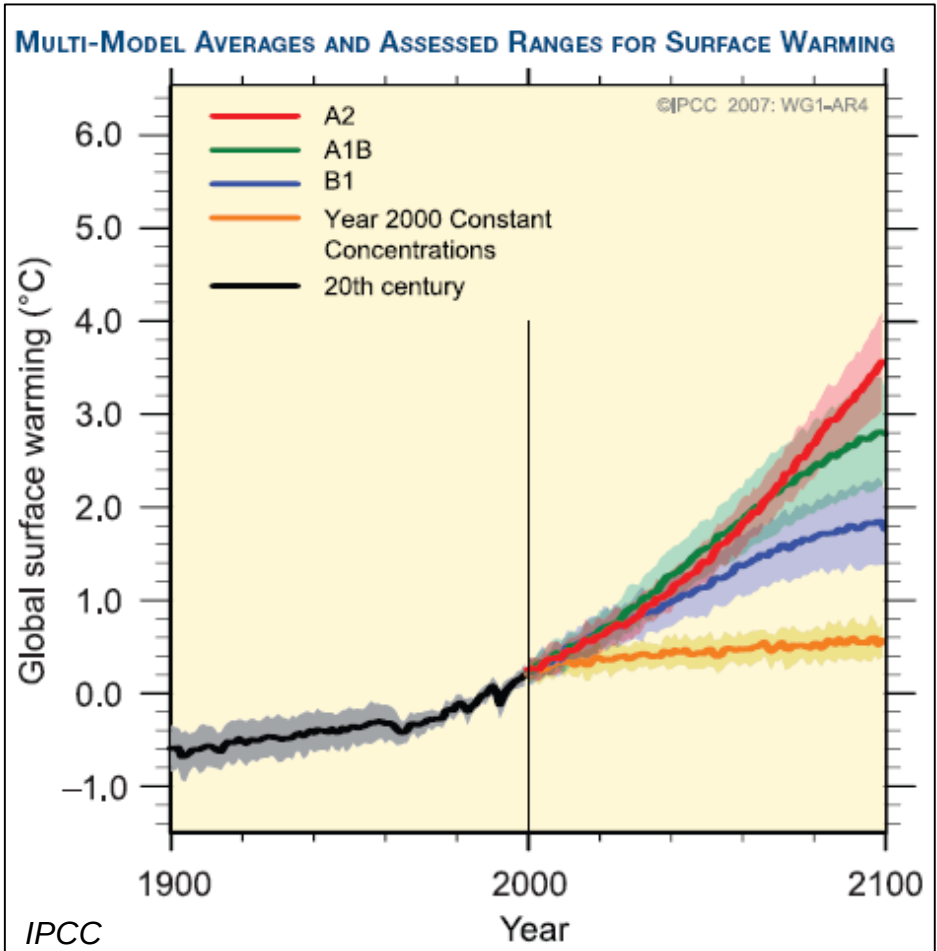
- Background on climate and health
  - Disease ecology
  - Pathogens of importance
- Explanation of modeling
- Overview of current work
  - San Juan, PR
  - Hermosillo, MX
- Future work
- Current challenges
- Creating an operational model
- Conclusions

Climate Variability and Change

- Shift in mean and variance of current conditions
- Increase in frequency of extreme conditions



IPCC

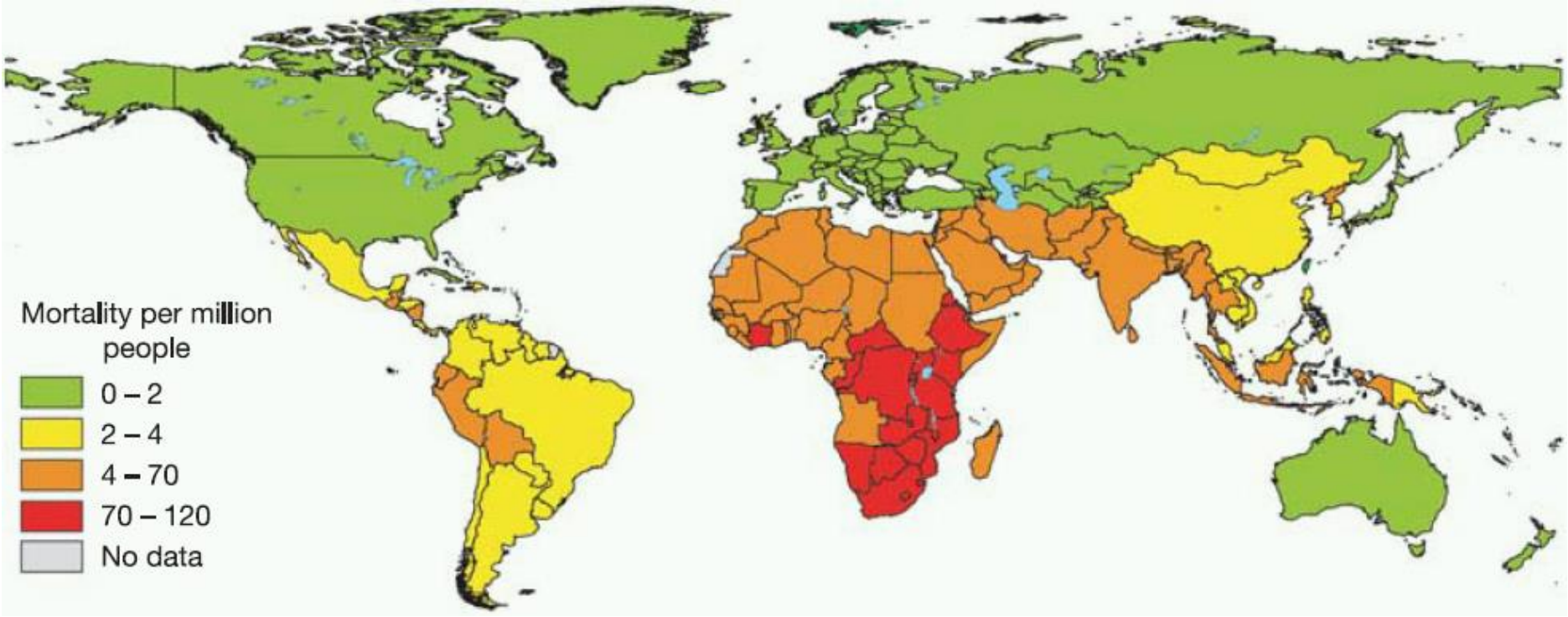


IPCC

Climate Change Deaths

- 150,000 lives annually over last 30 years (WHO)
- Who & where? How & why?

WHO estimated mortality attributable to climate change by the year 2000



Climate Effects on Human Health

Extreme Temperatures

Extreme Weather

- Flooding
- Hurricanes
- Tornadoes

Pathogens

- Vector-borne
- Water-borne
- Air-borne

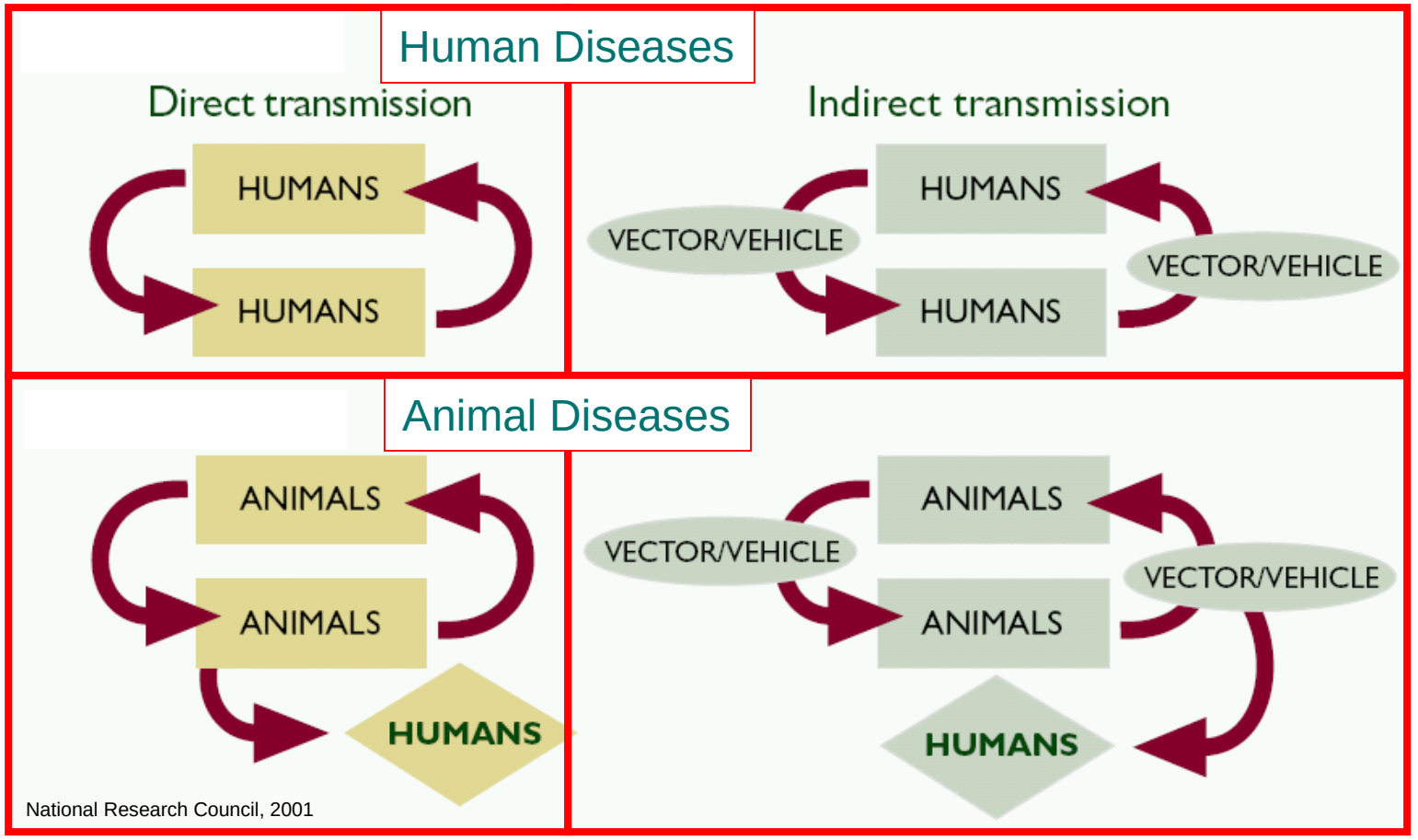
Air Quality

- Pollen
- Ozone
- Particulate Matter

Infectious Disease Transmission Cycles

TB, measles

malaria, dengue

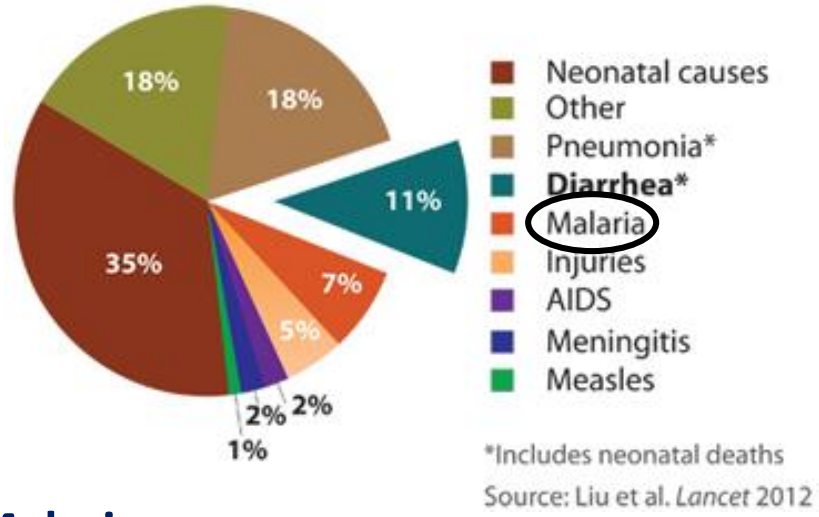


rabies

West Nile virus, Lyme

Leading Causes of Childhood Death

Children in Africa are 15 times more likely to die before the age of 5 than in developed nations (WHO)



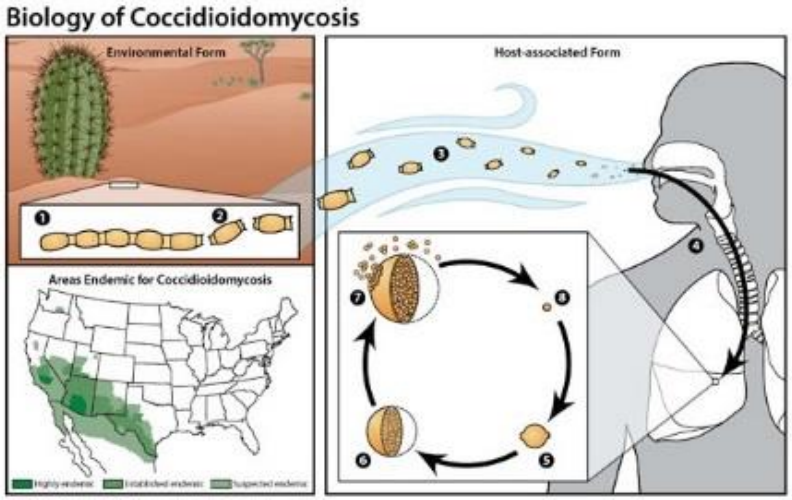
blog.oup.com

Malaria

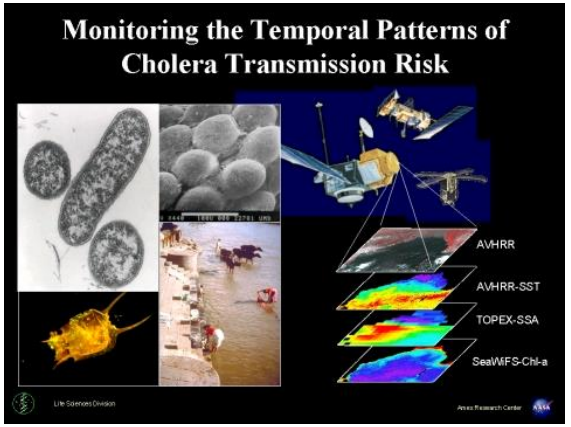
- World wide 627,000 deaths in 2012, (1500-2000/year in US)
- Symptoms can range from mild or absent to severe (causing death)
- Mosquitoes transmit one of four species of *plasmodium* parasites

Notable Environmentally Influenced Infectious Diseases

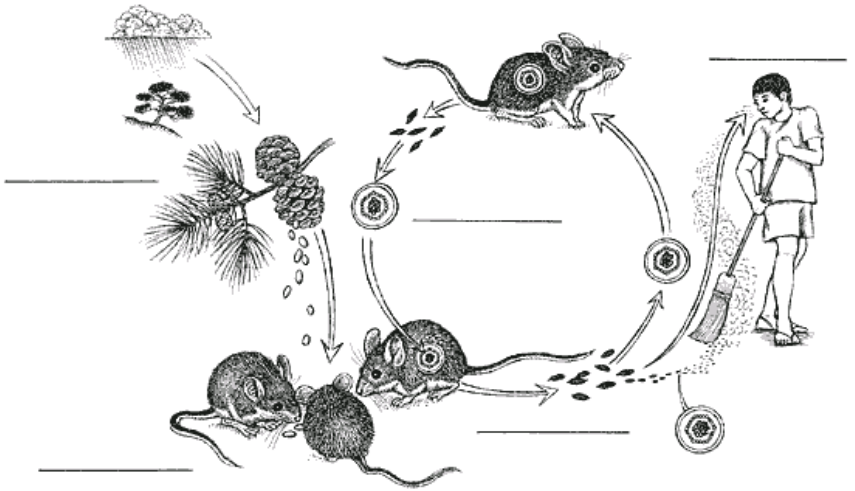
Valley Fever



Cholera

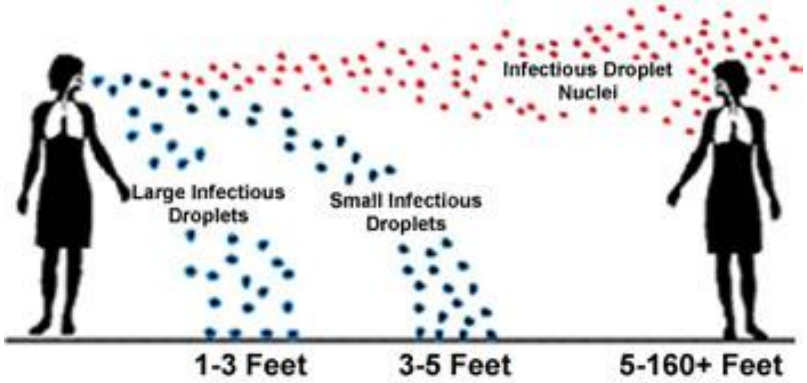


Hantavirus (HPS)



http://www.sdnhm.org/exhibits/epidemic/teachers/images/hanatvirus-cycle.gif

Influenza (Flu)



respiratory-supplies.medical-supplies-equipment-company.com

Vector-borne Diseases in the US

Dengue Viruses

- Annually ~ 96 million cases of symptomatic disease (WHO)
- Endogenous transmission in Texas and Florida
- Symptoms: muscle and bone ache, fever, and hemorrhagic manifestations in rare cases

Lyme Disease

- Transmitted by the tick *Ixodes scapularis* (*Ixodes pacificus)*
- Symptoms: rash, joint pain, headaches, arthritis
- 11-30,000 cases per year in US

West Nile Virus

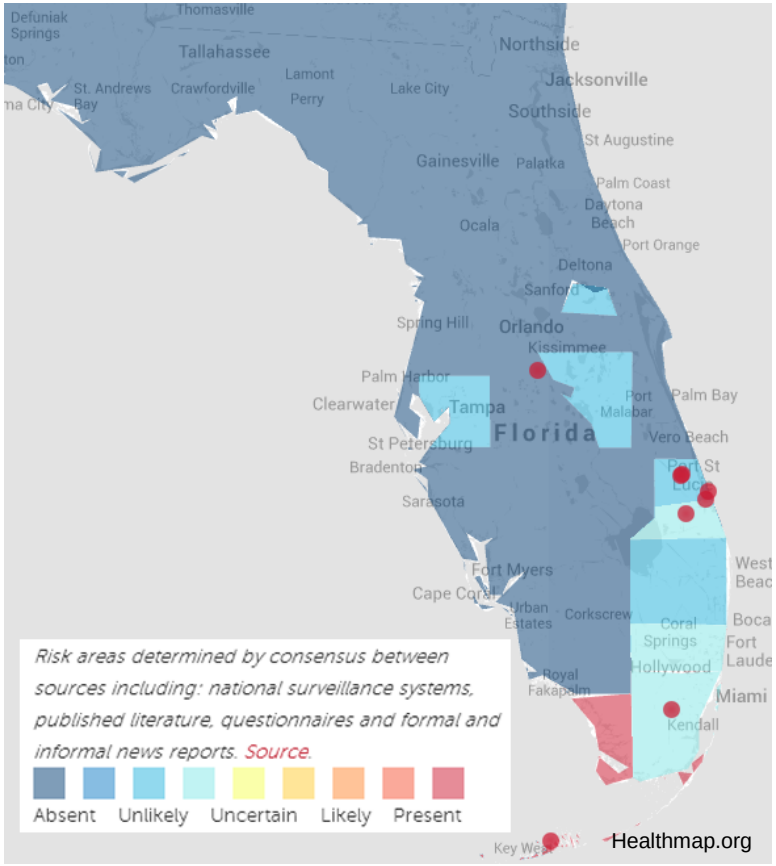
- In the US: 39,557 cases of disease and 1,668 deaths (CDC, 1999-2013)
- Disease ranges from mild fever to encephalitis and meningitis
- Now endemic in most of the United States

Chikungunya Virus

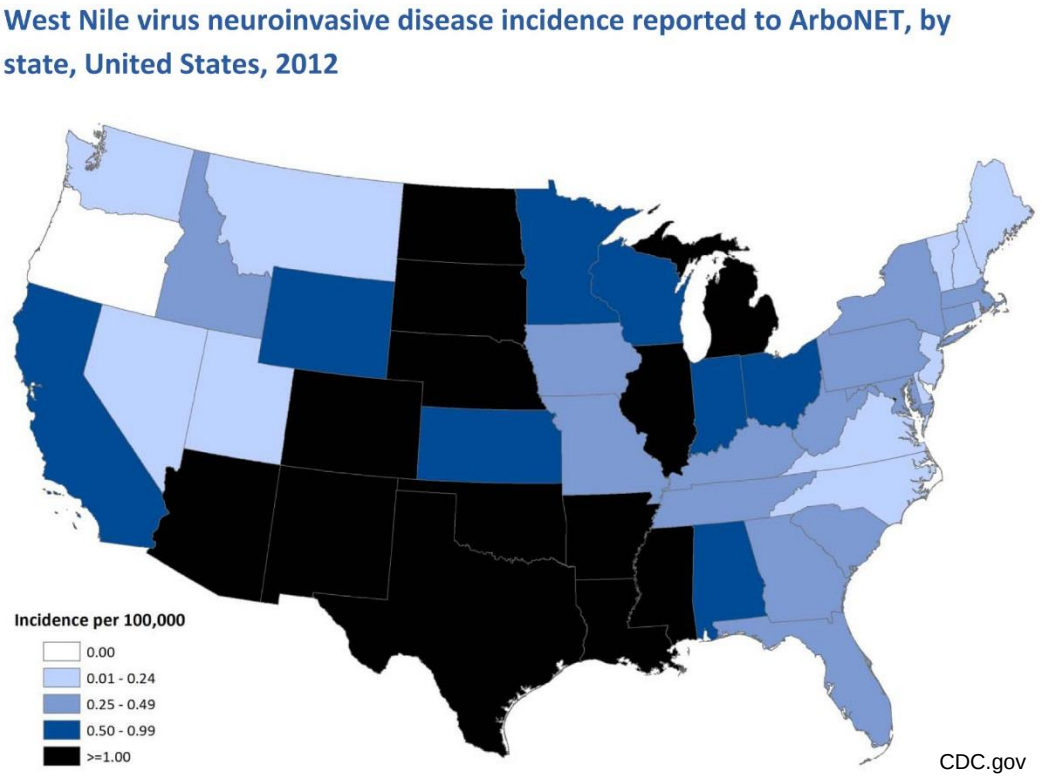
- In 2013 first locally acquired cases reported in the Americas
- Symptoms include fever, joint pain, headaches, and rash

How does climate affect mosquito-borne disease risk?

- Increases in the range of diseases



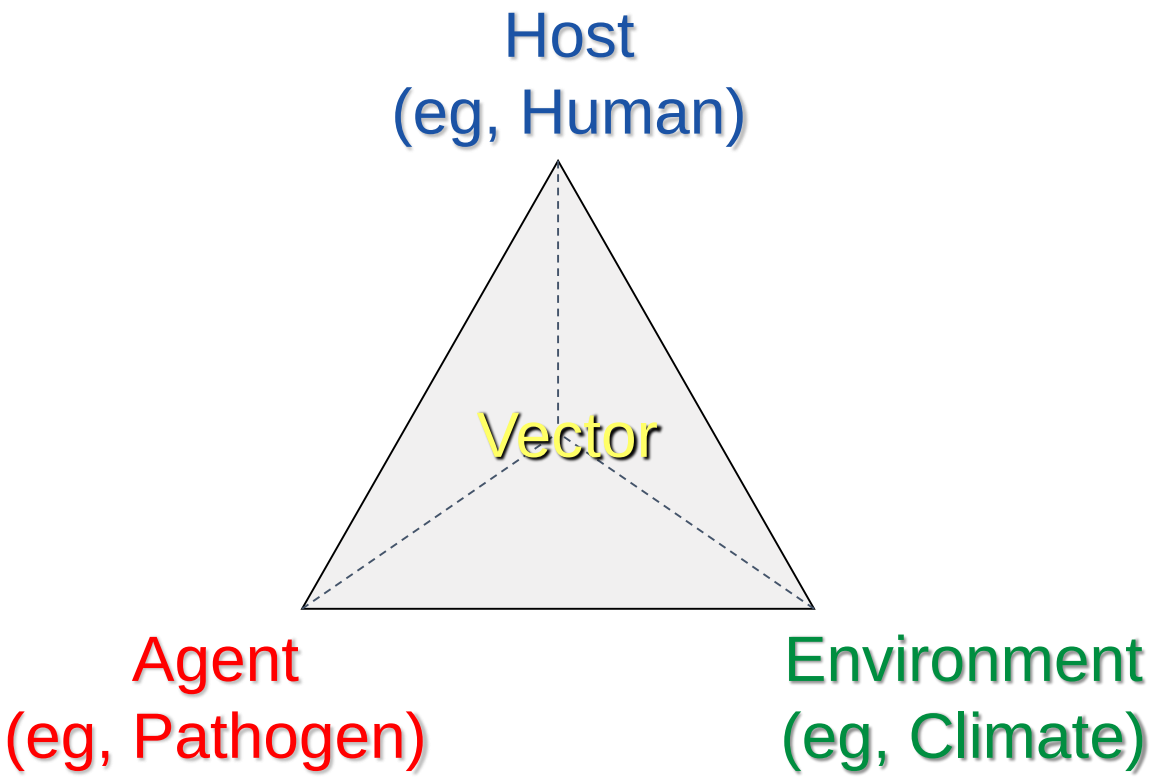
- Increases in the seasonality of diseases



Will transmission risk increase in the future and can we predict it?

Epidemiologic Triangle of Disease (Vector-borne Diseases)

- A *multi-factorial* relationship between hosts, agents, vectors and environment

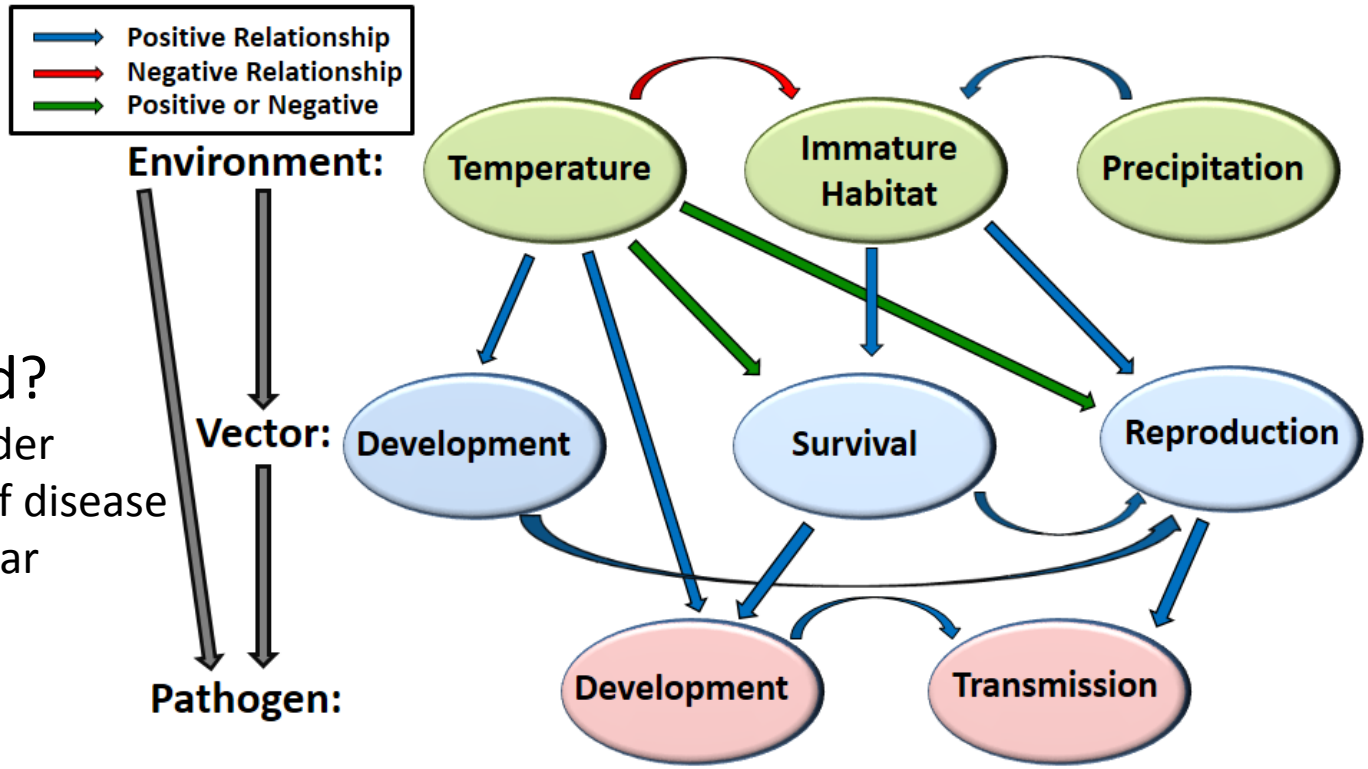


Systems Modeling

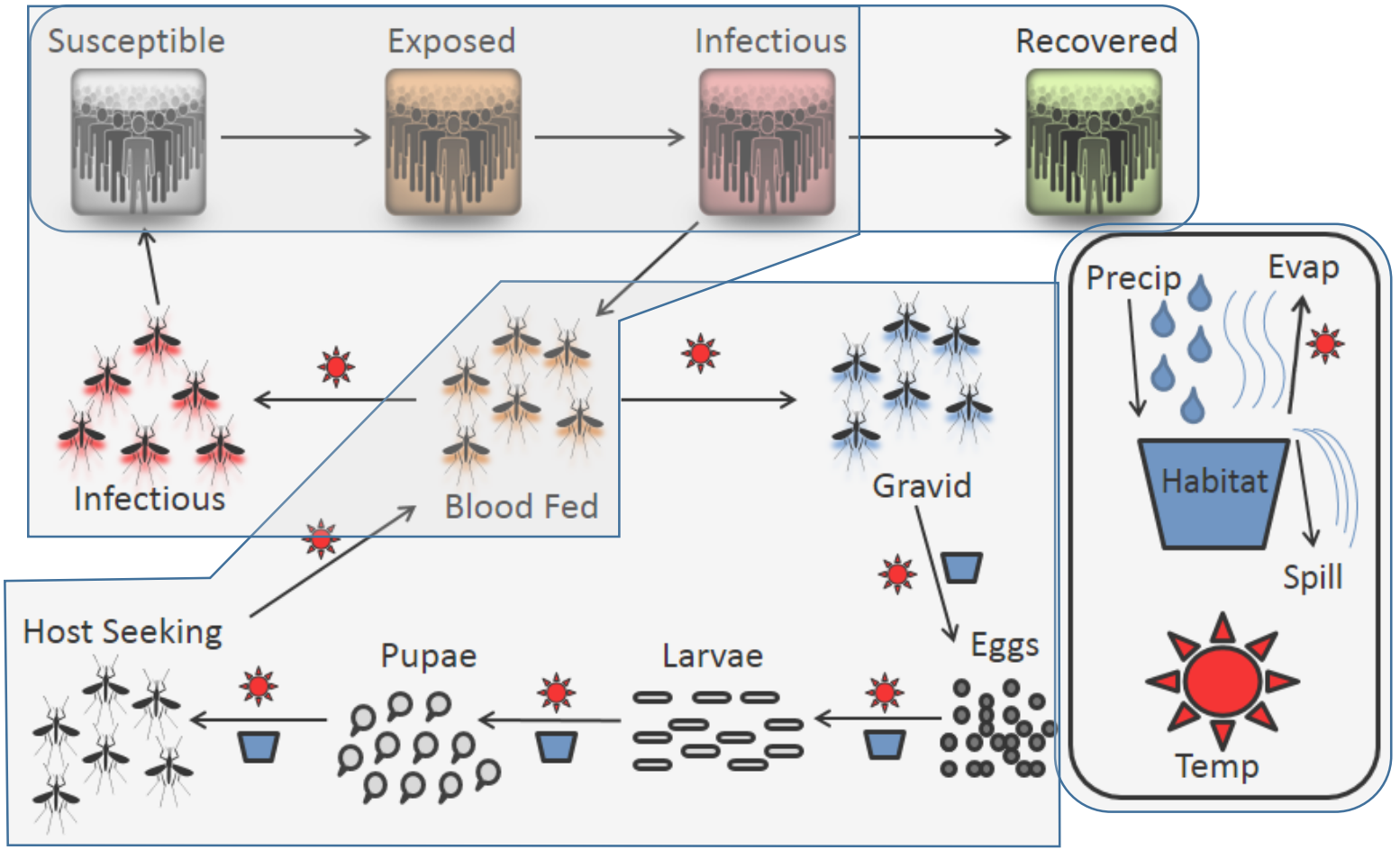
"A system is an interconnected set of elements that is coherently organized in a way that achieves something."

- Donella H. Meadows

- Why this method?
  - Allows us to consider multiple elements of disease ecology and nonlinear relationships



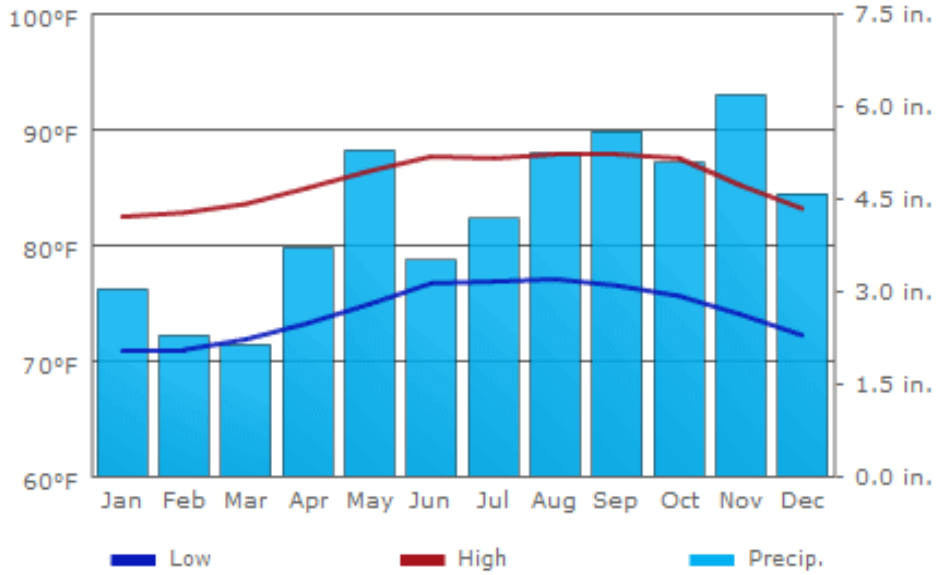
Modeling *Aedes aegypti* and Dengue Virus Ecology



Modeling Dengue Fever in San Juan, PR

- Vector population are not always reliable measures of transmission risk
  - Added pathogen and human transmission component to the model
- *Aedes aegypti* mosquitoes
  - Urban, container breeding
  - Live in tropical habitats
  - Anthropophilic
- San Juan, PR
  - Tropical climate
  - Seasonal precipitation
  - Endemic dengue
  - Seasonal cycles of transmission

http://www.interet-general.info/IMG/Aedes-Aegypti-2.jpg

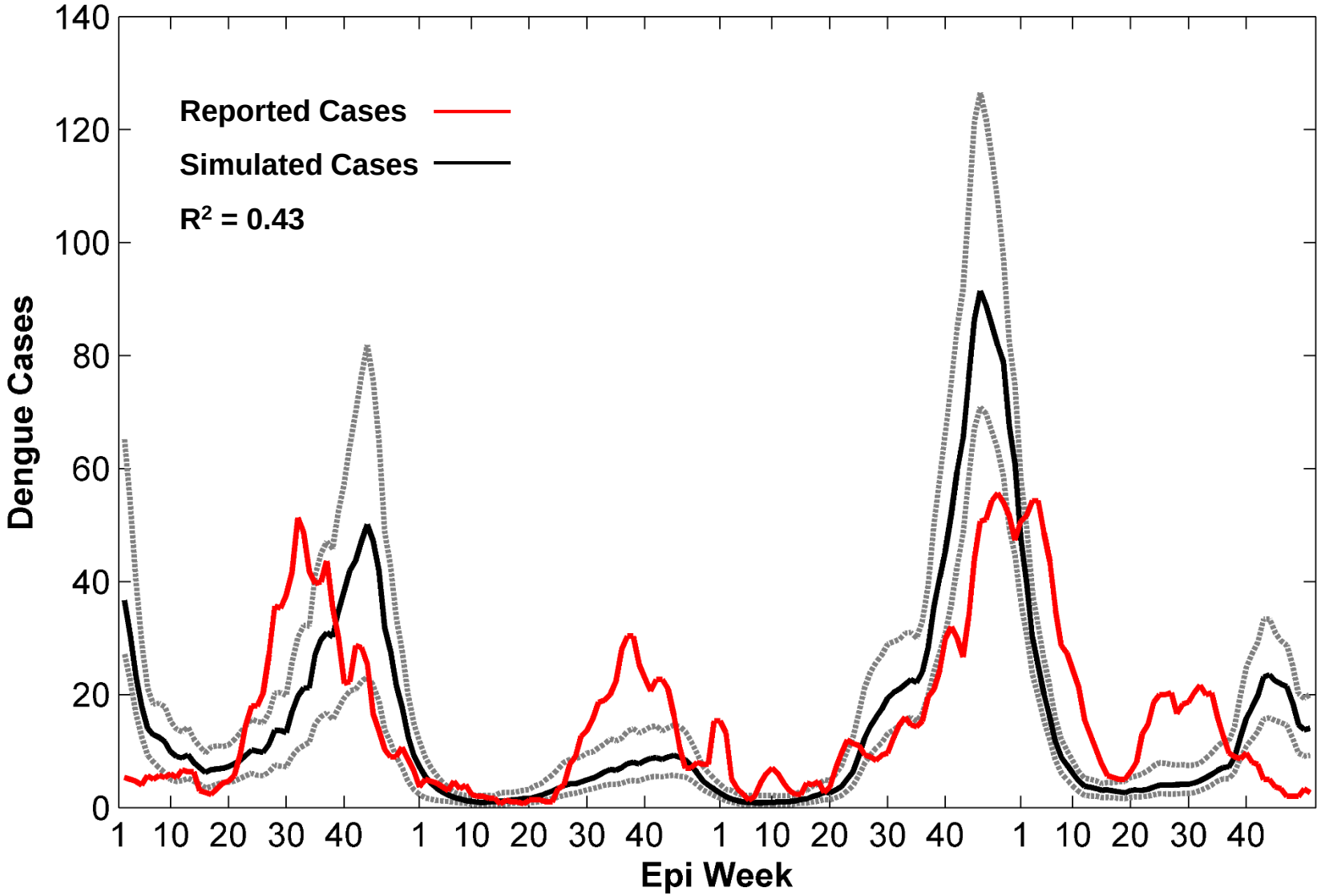


usclimatedata.com

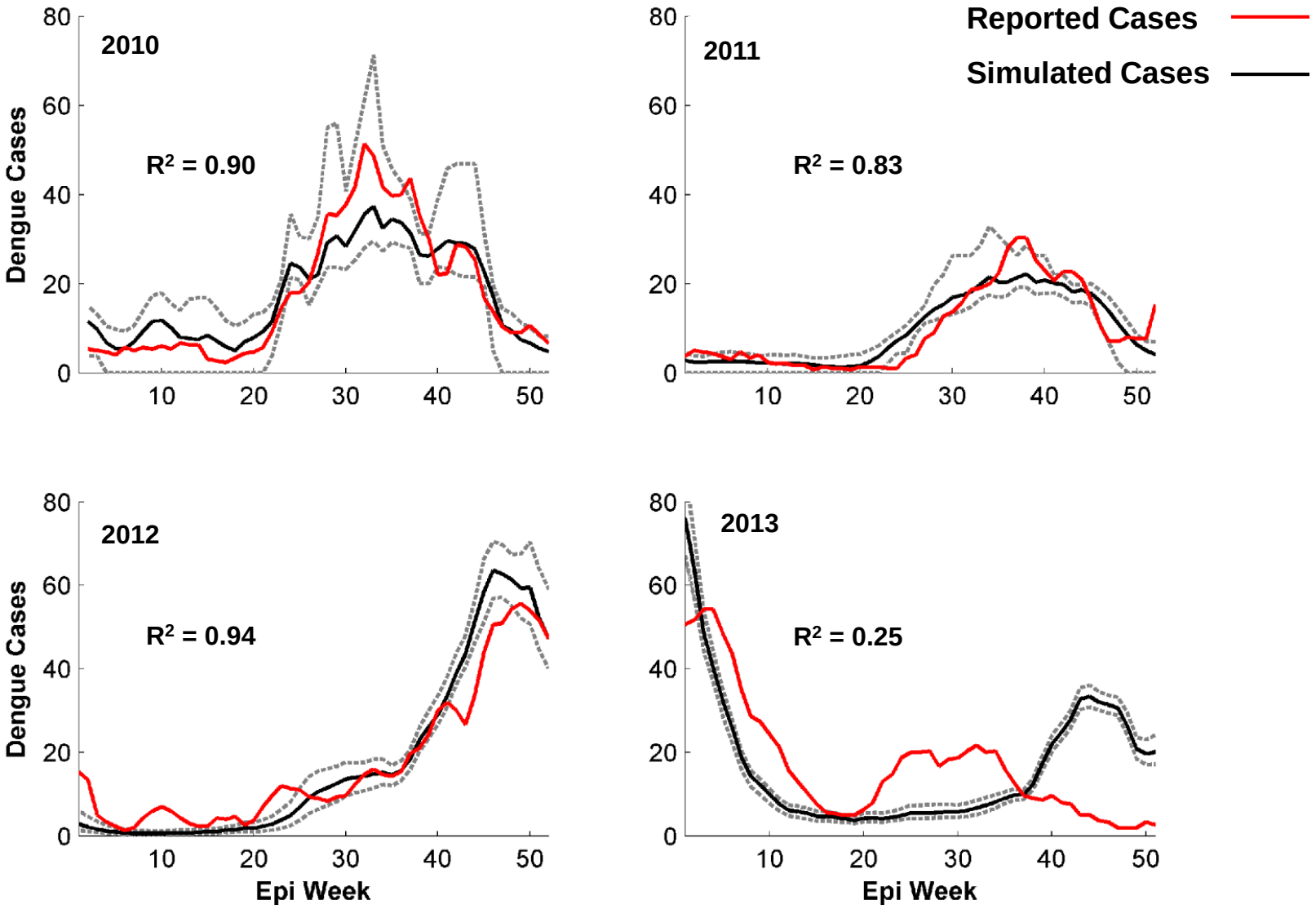
Data and Methods

- Study Area
  - San Juan Municipality, Puerto Rico
- Meteorological and Health Data
  - Daily maximum and minimum temperatures and total precipitation for San Juan, PR
  - Weekly clinically diagnosed dengue case counts for 2010-2013 from CDC for San Juan Municipality, PR
- Model
  - Parameterized for *Aedes aegypti* mosquitoes
  - Daily time step
  - Run over time period 2009-2013 under varying parameters
    - 9600 runs
  - Chose best 1% of runs by comparing output to CDC reported data
    - For entire time period and individual years

Simulation Results (Full Time Period)



Simulation Results (By Year)



Parameter Statistics

- Open containers vs. water storage
  - Climate dependence
  - Socioeconomic dependence

Proportion Uncovered Container	All	2010	2011	2012	2013
0.9	0	44	22	0	0
0.7	0	32	37	0	0
0.5	0	4	18	0	0
0.3	0	8	14	20	0
0.1	96	8	5	76	96

	2010	2011	2012	2013
Annual Precip	227.51	223.99	140.30	216.33

Conclusions: Modeling Dengue Fever in San Juan, PR

- Climate is a key regulator of dengue transmission in San Juan County, PR
  - Temperature limits viral replication during winter
  - Precipitation limits mosquito populations during spring
- Human response to weather and climate is important
  - Permanent water sources during dry years
- Non-climatic factors are important
  - Immunity, virus genetics, public health response

Modeling Dengue Fever in Hermosillo, MX

- Study area
  - Hermosillo, Mexico
  - Arid climate, summer monsoon
- Meteorological/Dengue case data
  - Daily maximum and minimum temperatures (NLDAS)
  - Daily precipitation (TRMM, NLDAS)
  - Weekly suspected dengue cases for Hermosillo, MX 2006-2011

www.travelnotes.org

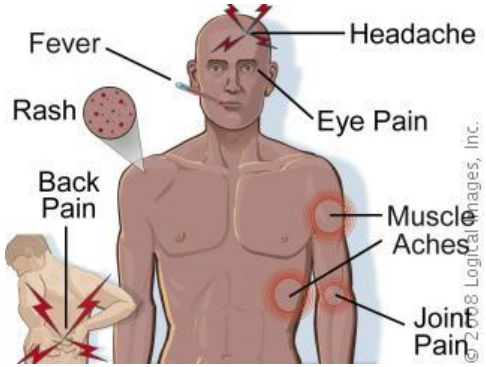
- Model
  - Parameterized for *Aedes aegypti* mosquitoes, daily time step
  - Run from 2005-2011 under varying parameters (500)
  - Best 3% of runs chosen by comparison with suspected case data (r^2)
    - For entire time period and individual years

Model Parameter Estimation

- Containers
  - Based on household surveys
  - Human managed and open containers
  - Used mean values and +/- 25% and 50%


Mosquitoeater.com


beingalison.com

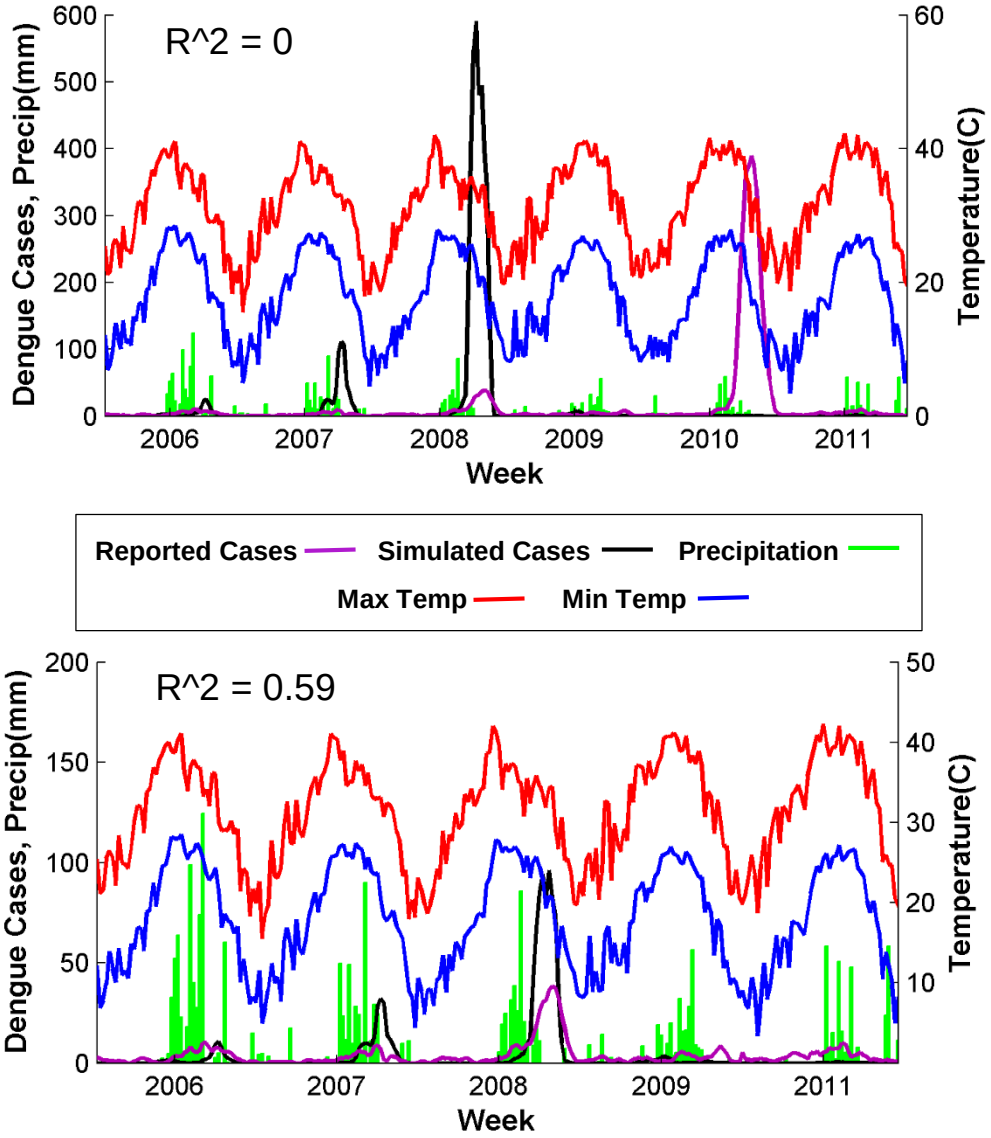


- Minimum infectious rate
  - Minimum amount of infectious humans
  - Maintains virus within the population
  - Based on case data and previous study in San Juan, PR

- Maximum larval density
  - Used to calculate density-dependent mortality
  - Based on observations, literature, and previous study in San Juan, PR

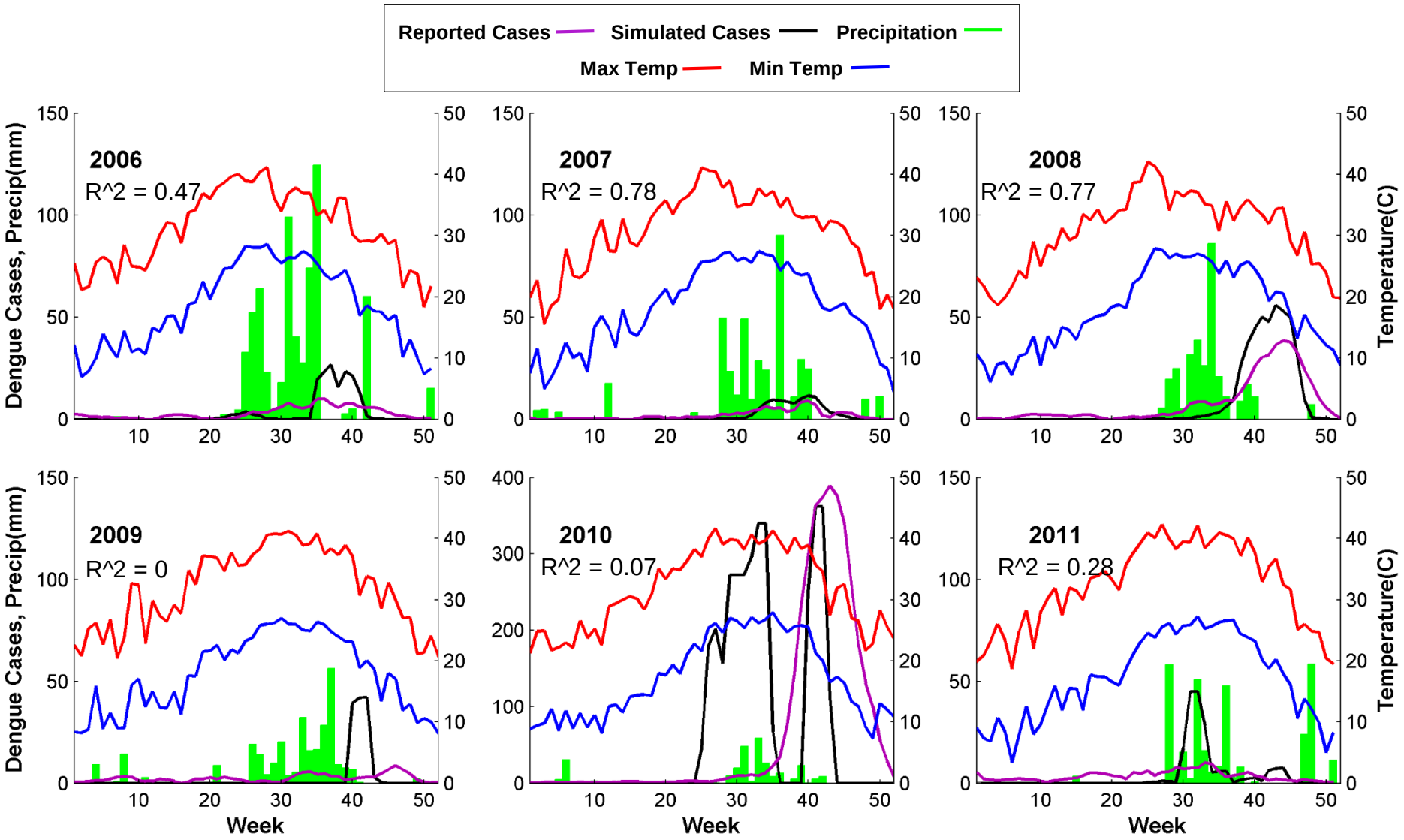

answers.yahoo.com

Simulation Results (Full Time Period)



- Simulations miss the 2010 epidemic
  - Not climate driven
  - Increased virus introduction
  - Serotype/Herd immunity
- Simulations improve when 2010 is excluded
  - Climate has greater influence
  - Seasonality driven by climate

Simulation Results (By Year)



Conclusions: Modeling Dengue Fever in Hermosillo, MX

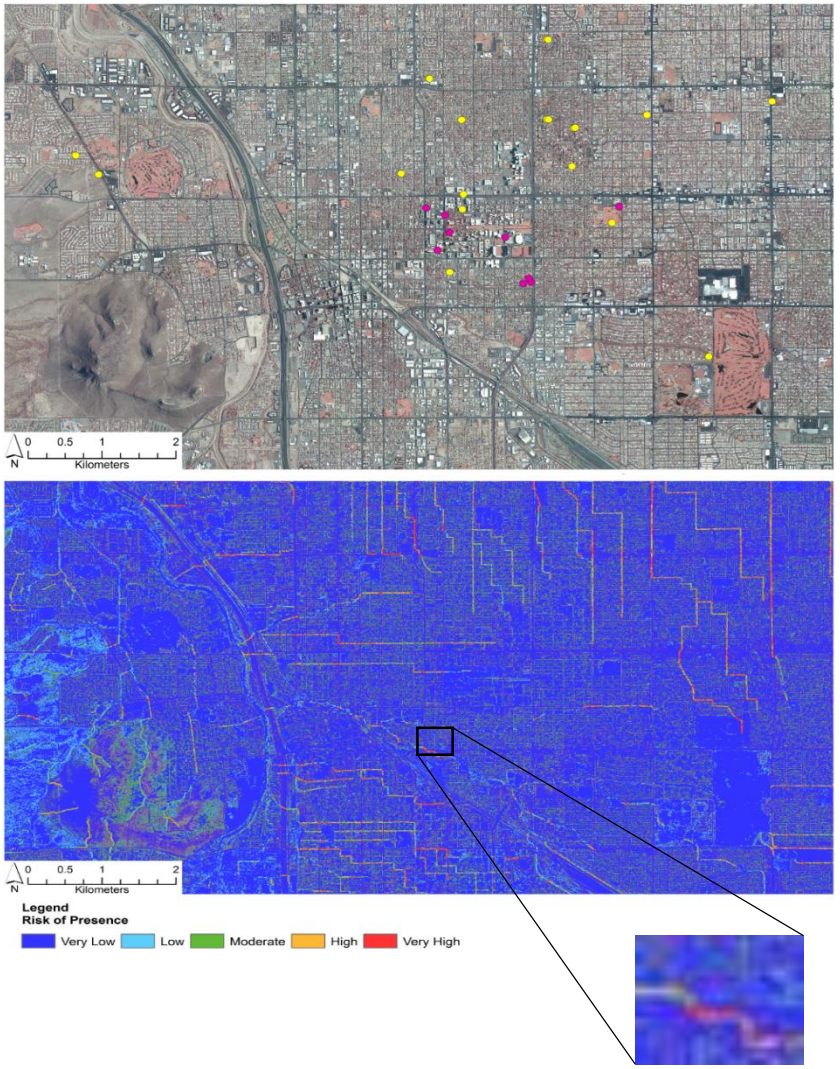
- Climate often influences the seasonality and amount of dengue transmission in Hermosillo Mexico
  - Model predicts a shorter/stronger season
    - Measured vs effective temperature
  - Model sometimes has difficulty simulating low case numbers
    - Randomness
- The influence of non-climatic factors is still very significant
  - Climate plays minimal role in 2010 epidemic
    - Serotype of virus, herd immunity, and virus introduction
    - Water storage
  - Climate/Transmission rate teleconnections

Next Steps (1)

- Perform simulations along US Mexico border
  - Examine if/how dengue transmission varies
  - Determine the role of climate in transmission disparities

Next Steps (2)

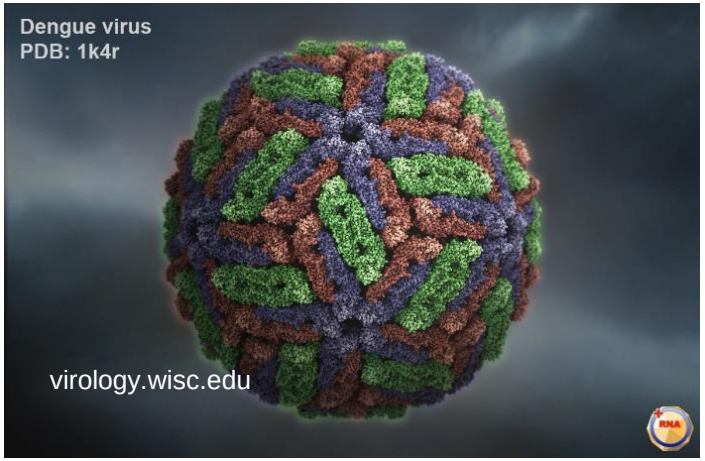
- Produce quantitative results that can be used by public health workers
  - Integration of remotely sensed data, GIS, and systems modeling
- Why/How does transmission risk vary across Hermosillo?
  - Water storage practices
  - Land cover types
  - Human population
  - Vegetation
- Inclusion of spatiotemporal dynamics



Challenges in Climate and Health Research

- Reporting problems
  - Misdiagnosis
  - Subclinical cases
  - Reporting errors/bias
  - Availability of data

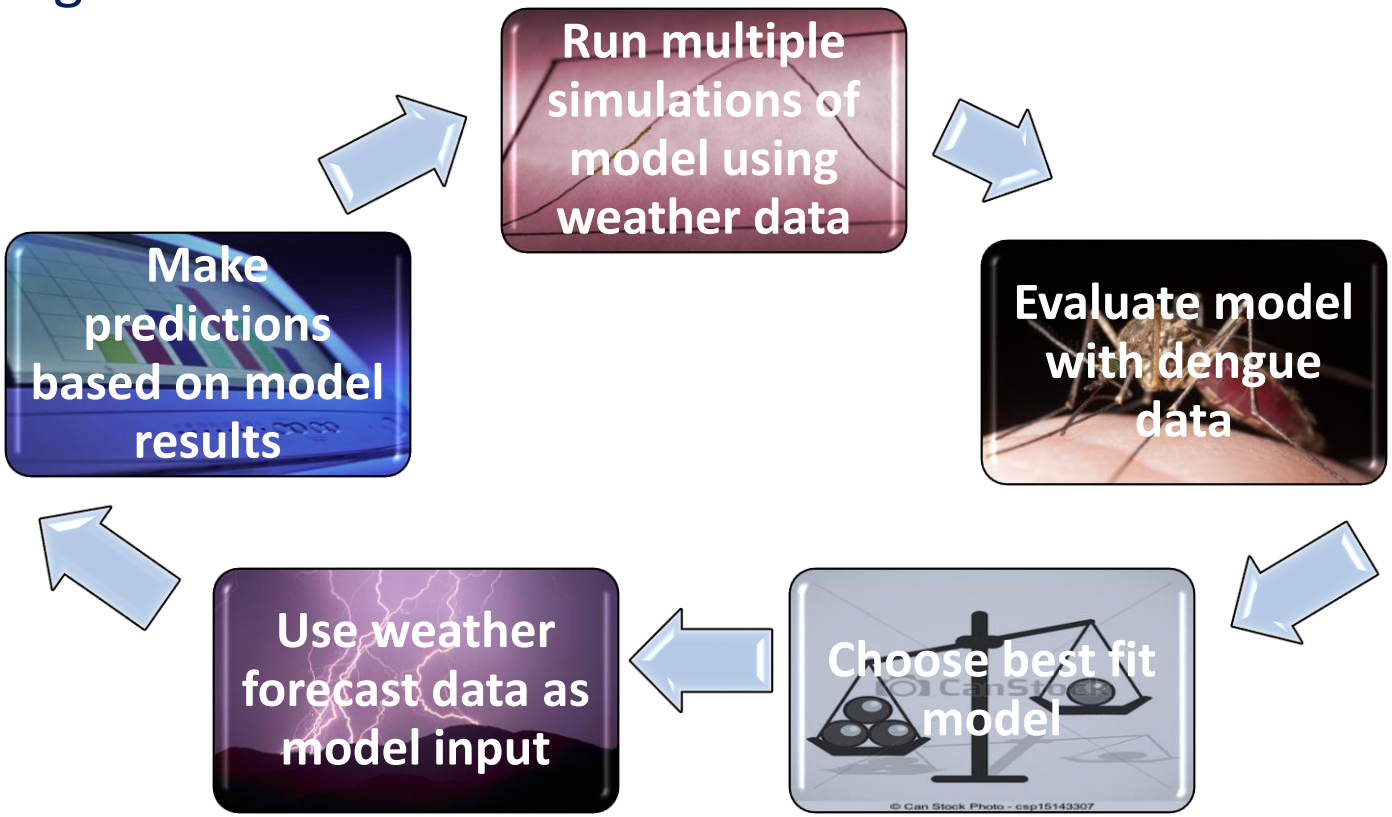
- Knowledge gaps
  - Incubation periods
  - Transmission probabilities
  - Evolution and adaption of virus and human immunity



- Human vs. climate influences
  - Socioeconomic status
  - Microclimatic influences
  - Human adaptions to climate

An Operational Model?

- Iterative : Using weather forecast and weekly reported dengue data



Conclusions

Natural and human systems are complex & coupled

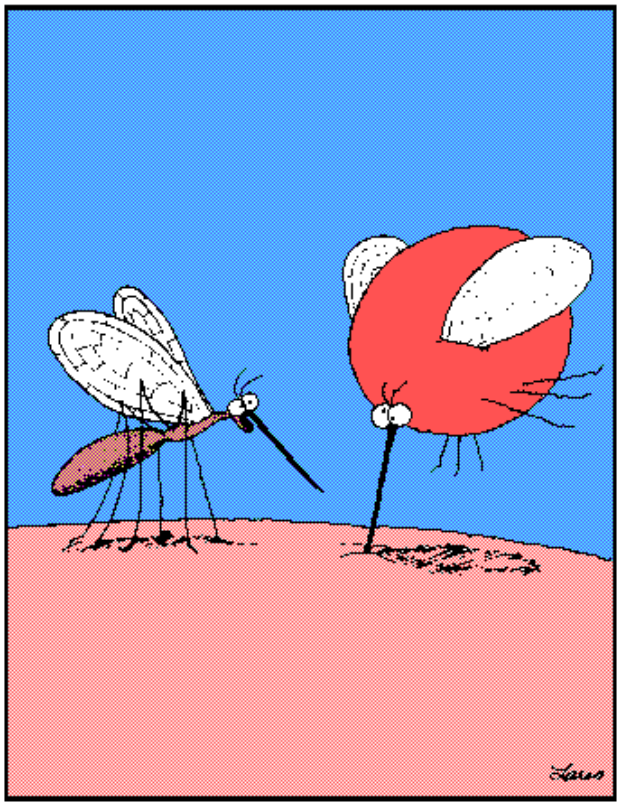
Pathogens remind us that we're not always at the top of the food chain

- Disease risk is not simply dictated by nature, it is socially constructed, creating differential vulnerability at the intersection of these systems

- Warmer and more extreme climate shifts will lead to (a) direct health impacts and (b) impacts exacerbated or mediated by social and ecological factors

- Complex system interactions raise the possibility of 'threshold behavior' in disease outbreaks

Thank You for Your Attention!



“Pull out, Betty! Pull out! ...
You’ve hit an artery!”