Meteorological Factors Limit *Aedes aegypti* Longevity and Dengue Virus Transmission in the Sonoran Desert

Cory Morin
NASA Postdoctoral Program Fellow
cory.morin@nasa.gov
A *multi-factorial* relationship between hosts, agents, vectors and environment

**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

**Chikungunya Virus**
- In 2013 first locally acquired cases reported in the Americas
- Symptoms include fever, joint pain, headaches, and rash
Weather/Climate Influences on Vector-borne Disease Ecology

Morin et al. 2013
Climate Variability and Change

- Shift in mean and variance
- Increase in frequency of extreme conditions
Challenges in Weather/Climate and Health Research (Vector-borne Diseases)

- **Knowledge gaps**
  - Vector population dynamics
  - Extrinsic Incubation Period (EIP)
  - Transmission probabilities
  - Evolution and adaption of virus and human immunity

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

- **Climate data**
  - Availability/Reliability
  - Resolution
  - Predictability

- **Human vs. climate influences**
  - Socioeconomic status
  - Microclimatic influences
  - Human adaptions to climate
Investigating Dengue Transmission in Sonora, Mexico

- Sonora, Mexico
  - Arid climate, monsoon precipitation
  - Seasonal/annual cycles of dengue transmission
  - Large variations in case loads between the northern and southern regions
  - Inhabited by *Aedes aegypti* mosquitoes
    - Anthropophilic, dengue vector

- Why is dengue transmission common in Hermosillo while there is little/no transmission in nearby Nogales?

- Hypothesis: Cooler temperatures in Nogales
  - Suppression of mosquito population
  - Extension of extrinsic incubation period (EIP)
Data and Methods

• Meteorological/Dengue case data
  • Daily maximum and minimum temperatures (NLDAS)
  • Daily precipitation (TRMM, NLDAS)
  • Weekly suspected dengue cases for Hermosillo, MX 2006-2011

• Dynamic Mosquito Simulation Model (DyMSiM)
  • Simulates *Aedes aegypti* population and dengue virus transmission dynamics
  • Run from 2006-2011 (500 simulations)
  • Parameterization performed using suspected dengue case data

• Experiments
  • Control: Performed simulations for Hermosillo and evaluated with reported case data
  • 1: Rerun simulations using Nogales meteorological data
  • 2: Rerun experiment 1 with 1°C warming
Modeling *Aedes aegypti* and Dengue Virus Ecology
Model Parameter Estimation

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

• 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
Control: Simulating Dengue Cases in Hermosillo

- 2008 and 2010 are largest dengue years
  - Use for Nogales comparison simulations
- Generally epidemics follow monsoon rains
- Precipitation magnitude has little influence on dengue magnitude
- Introduction from nearby areas is likely important
Experiments: Dengue Cases and Mosquitoes

- Little/no dengue is simulated under Nogales meteorological conditions
- With warming, there is a modest mosquito population increase in 2008
  - No dengue
- Warming increases the mosquito considerably population in 2010
  - Results in increased virus transmission
Experiments: Dengue Cases and EIP

- EIP is considerably longer under Nogales conditions
- Under Nogales conditions, the EIP is longer during the transmission season in 2008 compared to 2010
  - Prevents completion of EIP during mosquito lifetime
- EIP shortened under 1°C warming conditions
  - Small change produces dramatic shift in dengue fever cases
Conclusions

• Climate is an important regulator of dengue transmission in Sonora, MX
  • Precipitation influences the timing but not magnitude of dengue epidemics
  • Temperature influences mosquito population dynamics and the virus EIP
    • Small changes in temperature can have significant impacts on transmission
  • Year to year climate variability is important especially along fringe regions
    • Difference in dengue transmission suitability in Nogales between 2008 and 2010

• Dengue transmission dynamics in northern Mexico may affect dengue risk in the United States
  • Travel, climate change
  • Recent dengue epidemic in Nogales
Thank You for Your Attention!

Cory Morin, cory.morin@nasa.gov

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