Challenges and Opportunities for Modeling Dengue and Chikungunya

Michael Johansson
Mosquito-borne disease models

Modeling for decisions:
chikungunya & dengue

Michael Johansson

The findings and conclusions are those of the author and do not necessarily represent the official position of the Centers for Disease Control and Prevention.
EVERY decision is based on a model.
EVERY public health decision is based on a model.
EVERY public health decision is based on a model.

Public health decisions CAN be informed by quantitative models.
EVERY public health decision is based on a model.

How?

Public health decisions CAN be informed by quantitative models.
A pathway for informing decisions

1. Establish objectives and targets
2. Identify, acquire, and/or simulate data
3. Formulate models
4. Evaluate predictions
Targets

Key characteristics

- Common language
- Decision-oriented
- Measurable
Targets

What is the probability of an infected traveler arriving and initiating local transmission in _______?
Data

Key characteristics

- Outcome-oriented
- Training & testing
- Future availability
- Public
Data

1. Incidence

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<th>Suspected Cases</th>
<th>Incidence rate</th>
<th>Confirmed Cases</th>
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Data

1. Incidence
2. Movement
   - Long-term change
   - Differences for cases
   - Response to epidemic
Data

1. Incidence
2. Movement
3. Transmissibility
   - Infectious period
   - Mosquito spp./strain
   - Mosquito abundance
   - Vector competence

![Graph showing the relationship between temperature and R0](image)
Model

Probability of local transmission

\[ p_{AUTO}(i,m) = 1 - \prod_{s \in S} \left( 1 - p_{i,s,m} + p_{i,s,m} e^{R_{0i,m}^L (e^{-R_{0i,m}^R} - 1)} \right)^{I_{s,m}D} \]

Johansson et al., *PLOS One*, 2014
Model

Johansson et al., *PLOS One*, 2014
Evaluation

Key characteristics

- Make predictions public
- Use a baseline
- Evaluate on external data
- Estimate accuracy
- Compare uncertainty
Nowcasting the Spread of Chikungunya Virus in the Americas

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Abstract

Background: In December 2013, the first locally-acquired chikungunya virus (CHIKV) infections in the Americas were reported in the Caribbean. As of May 16, 5,592 cases had been reported and the outbreak was still spreading. Identification of newly affected locations is paramount to intervention activities, but challenging due to limitations of current data on the outbreak and on CHIKV transmission. We developed models to make probabilistic predictions of spread based on current data considering these limitations.

Methods and Findings: Branching process models capturing travel patterns, local infection prevalence, climate dependent transmission factors, and associated uncertainty estimates were developed to predict probable locations for the arrival of CHIKV-infected travelers and for the initiation of local transmission. Many international cities and areas close to where transmission has already occurred were likely to have received infected travelers. Of the ten locations predicted to be the most likely locations for introduced CHIKV transmission in the first four months of the outbreak, eight had reported local cases by the end of April. Eight additional locations were likely to have had introduction leading to local transmission in April, but with substantial uncertainty.

Conclusions: Branching process models can characterize the risk of CHIKV introduction and spread during the ongoing outbreak. Local transmission of CHIKV is currently likely in several Caribbean locations and possible, though uncertain, for other locations in the continental United States, Central America, and South America. This modeling framework may also be useful for other outbreaks where the risk of pathogen spread over heterogeneous transportation networks must be rapidly assessed on the basis of limited information.

www.cdc.gov/chikungunya/modeling/
Evaluation
Evaluation
Uncertainties
Estimated suitability for *Aedes aegypti*
Complex interactions

Nuevo Laredo, Mexico
- Recent Infection: 16%
- Past Infection: 48%
- Ae. aegypti index: 25%

Laredo, USA
- Recent Infection: 1%
- Past Infection: 23%
- Ae. aegypti index: 37%

Reiter et al., *EID*, 2003
Dengue in Puerto Rico

Reported cases (monthly)

Year:
- 1985
- 1990
- 1995
- 2000
- 2005
- 2010
Targets

What will the peak incidence be?
Model 1: $R^2 = 0.16$ for 44 cases
Model 2: $R^2 = 0.19$ for 47 cases
Mean error = 62 cases
Max error = 130 cases

Peak incidence
Dengue Forecasting Project

Targets: Peak incidence, peak timing, and total cases

Data: Public data release: San Juan and Iquitos (inc. serotype + environmental)

Evaluation: Testing/training, quantitative metrics

Models: Any

predict.phiresearchlab.org
dengueforecasting.noaa.gov
NCEP Operational Forecast Skill
36 and 72 Hour Forecasts @ 500 MB over North America
[100 * (1-S1/70) Method]
Acknowledgements

Luis Mier-y-Teran
Matt Biggerstaff
Ann Powers
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Nicole Cohen
Erin Staples