

System dynamics of dengue transmission in Singapore

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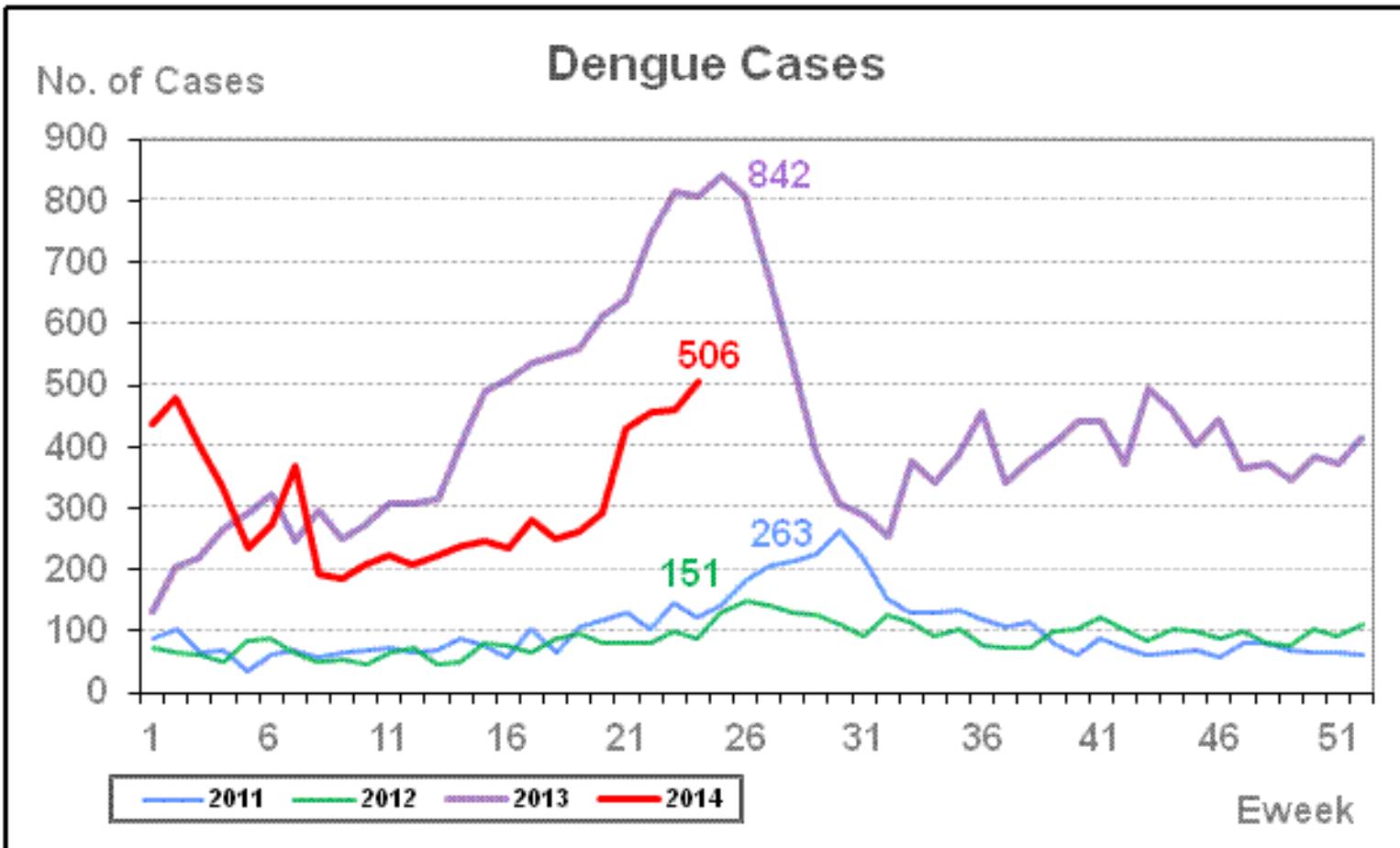


Motivation

- Global resurgence of dengue
 - Among the most important infectious diseases in the world
- Periodic and recurring outbreaks in Singapore
 - Severe outbreaks in 2005 and 2007
 - Singapore currently experiencing an outbreak



Dengue Cases



Characteristics of dengue

- Four serotypes of virus (DEN-1 to DEN-4)
- Vector-transmitted disease (Aedes mosquito)
- Incubation period of virus (4-10 days)
- Range of severity of symptoms in patients
 - Subclinical dengue (asymptomatic)
 - Classical dengue
 - Dengue haemorrhagic fever
- Immune Enhancement

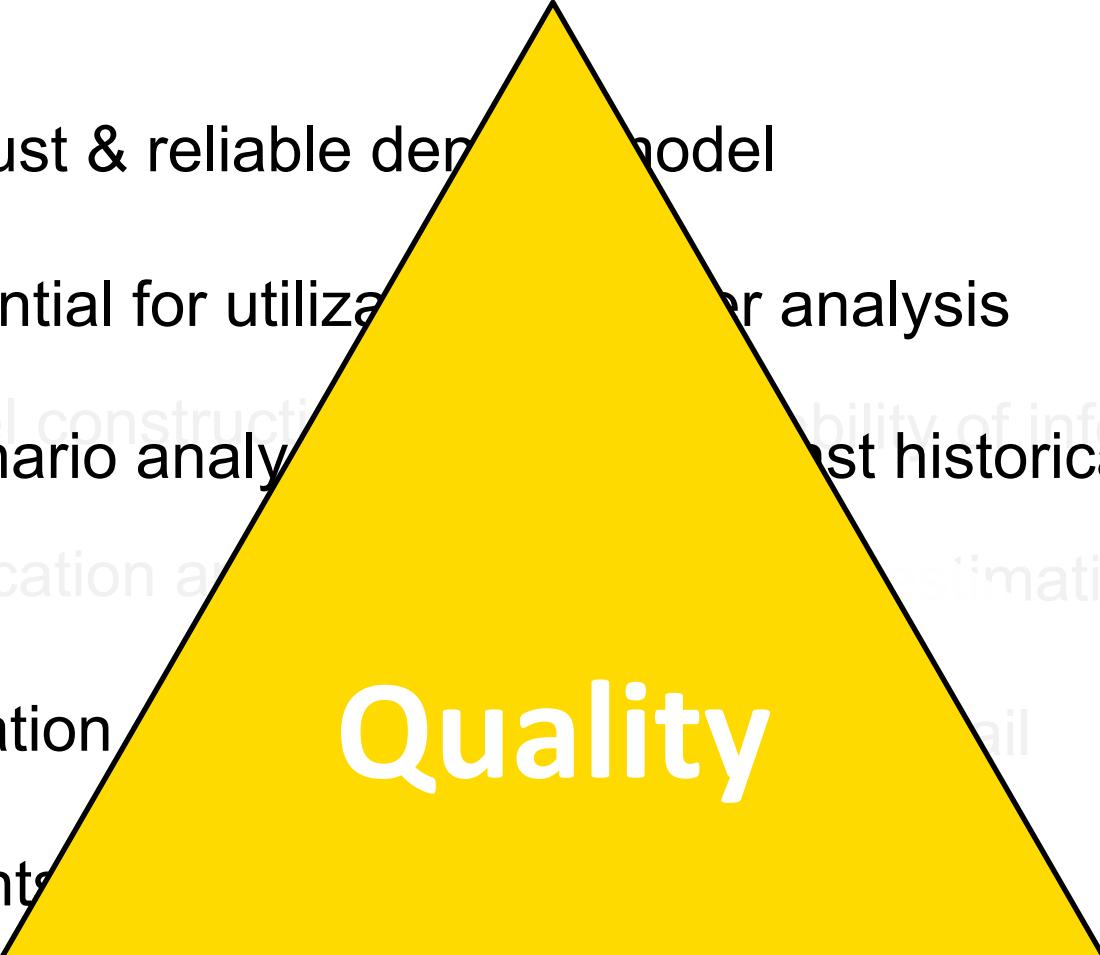


Lit review: system dynamics modelling

- Significant contribution to malaria control
- Other modelling approaches
 - Statistical models
 - Agent-based models
- Pragmatic middle ground between level of detail and computing effort
- Lack of robust system dynamics models for Singapore context



Project objectives



• Robust & reliable dependency model

• Potential for utilization of historical data

• Scenario analysis

• Verification and validation

• Insights

• Model construction

• Sensitivity analysis

• Uncertainty of information

• Cost historical data

• Estimations

• Tailored

• Validation

• Quality

Methodology

- Qualitative analysis
 - Causal loop diagram
 - Understand interdependencies among factors
- Quantitative analysis
 - Stock-and-flow model
 - Understand scale and impact of various factors
 - Simulation run for 2005-2008 Singapore DEN-2 cases

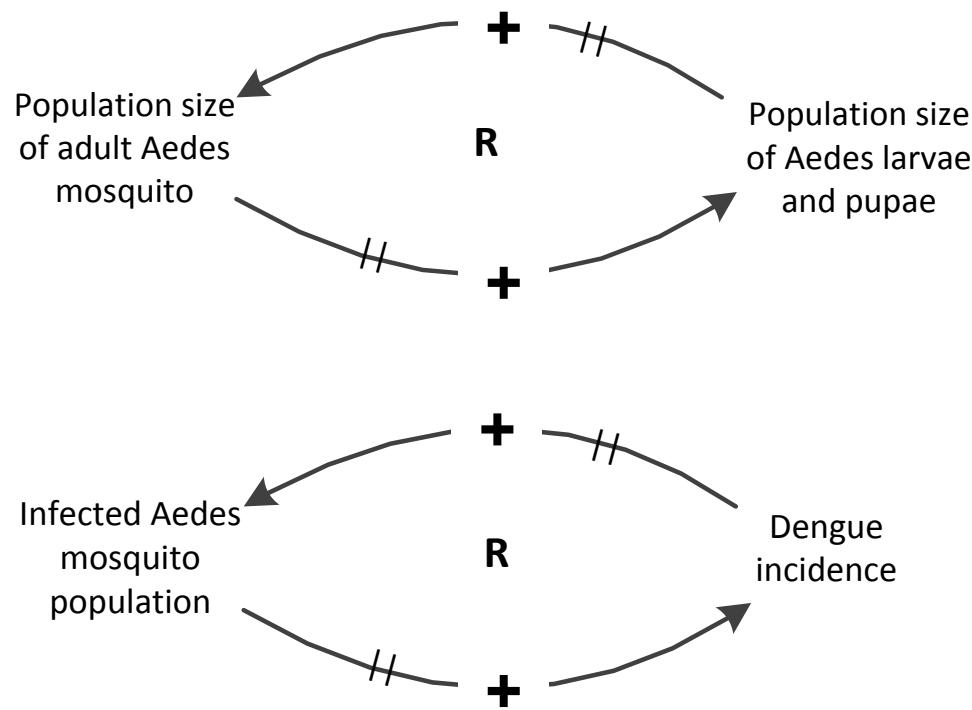


QUALITATIVE ANALYSIS



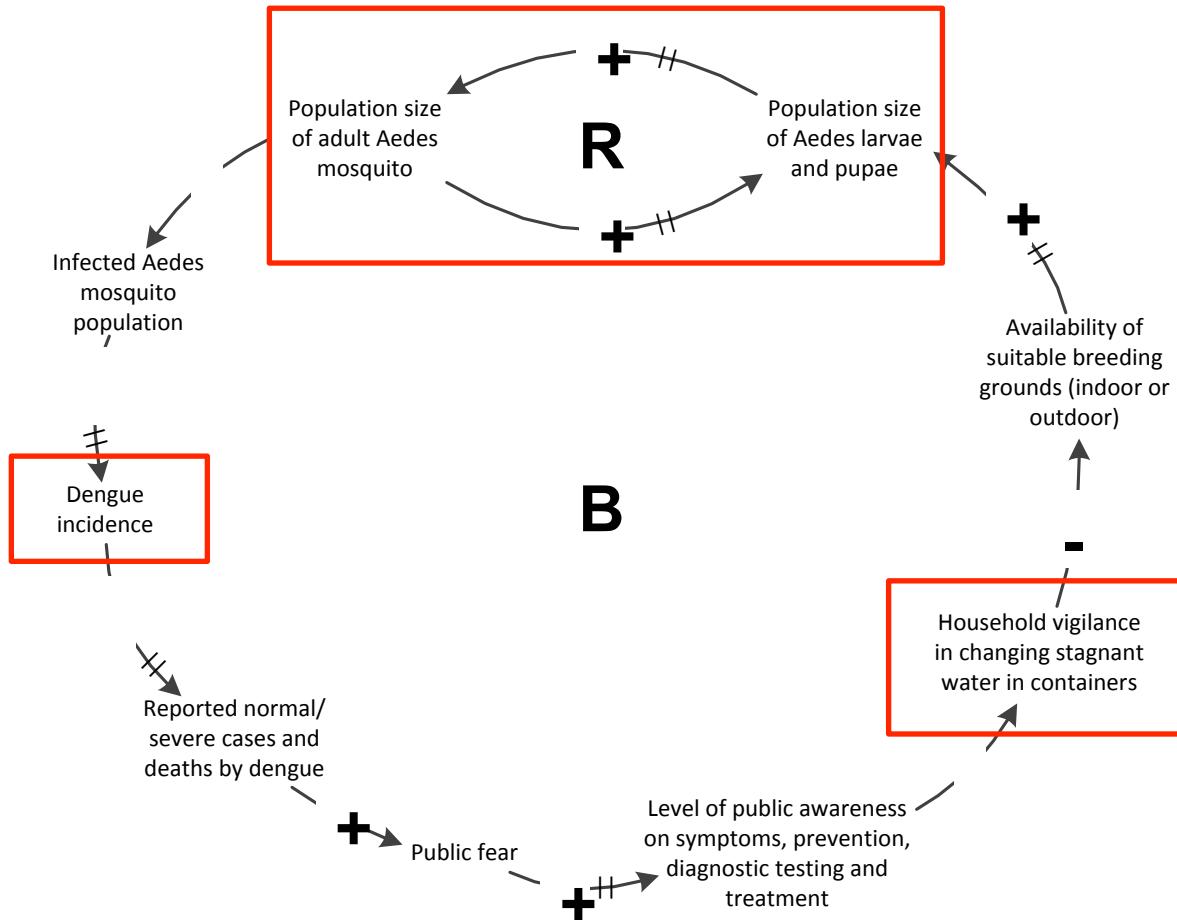
Causal loop diagram

- Vector populations and dengue incidence



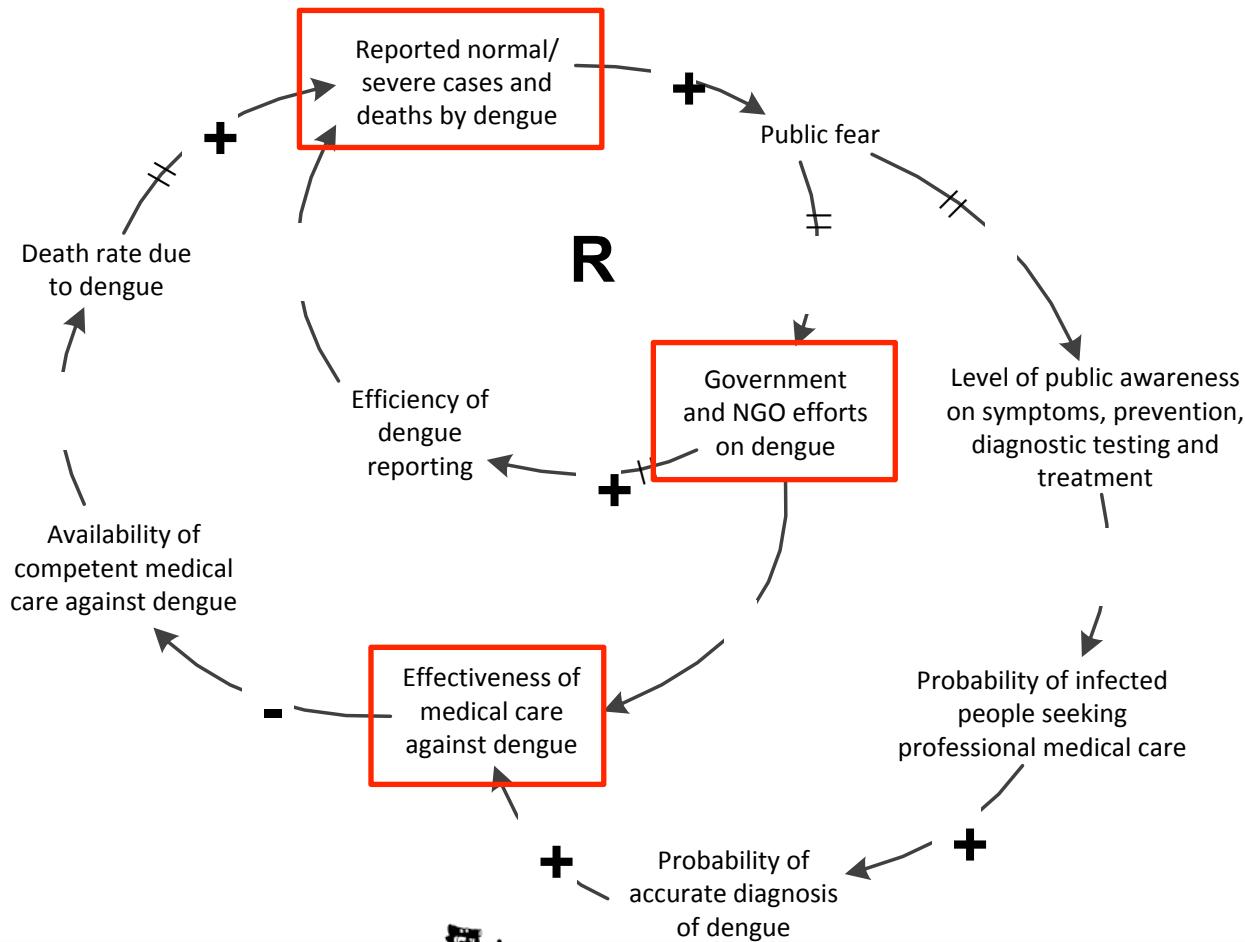
Causal loop diagram

- Public reaction to dengue



Causal loop diagram

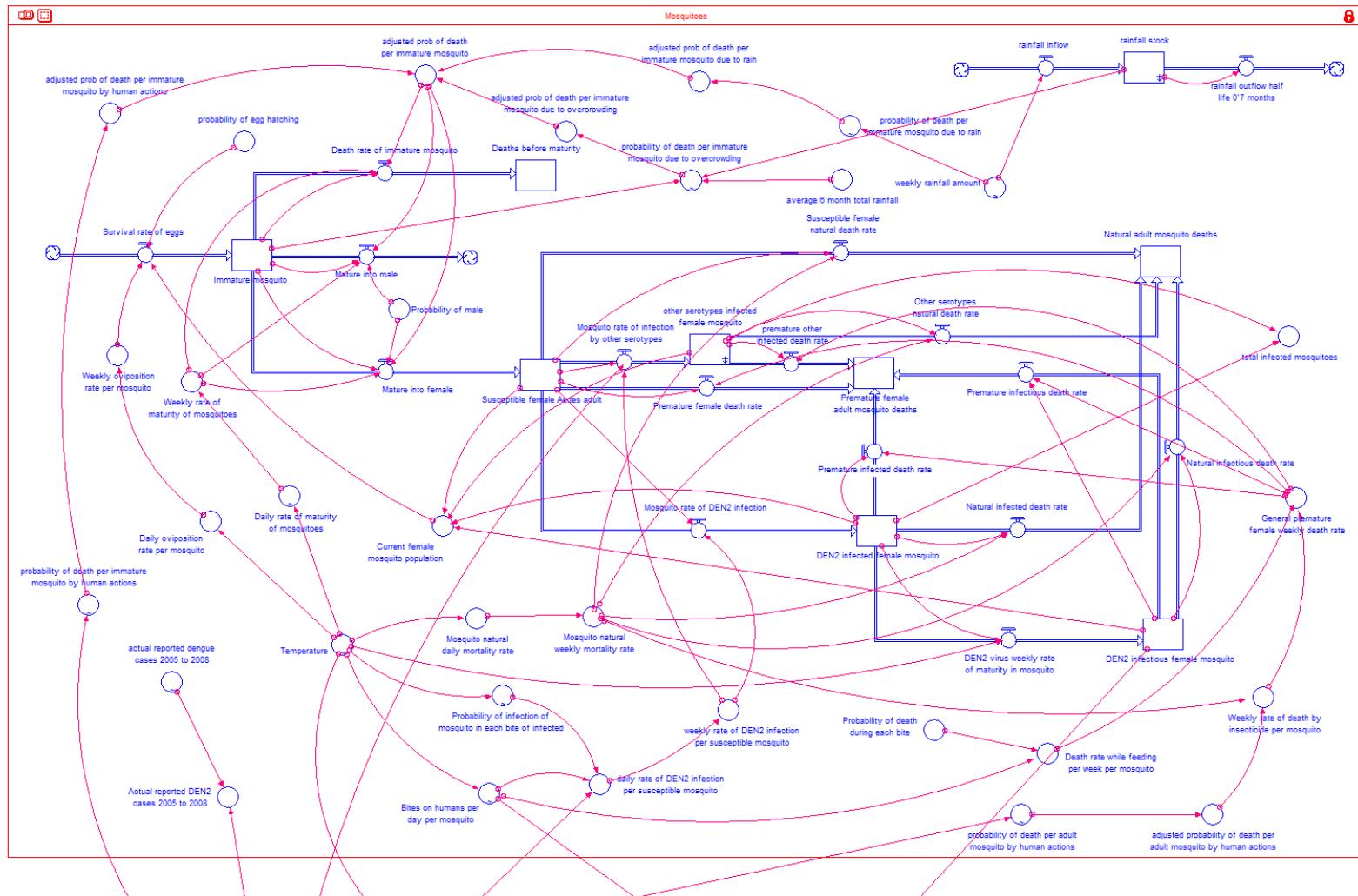
- Government policies and medical care



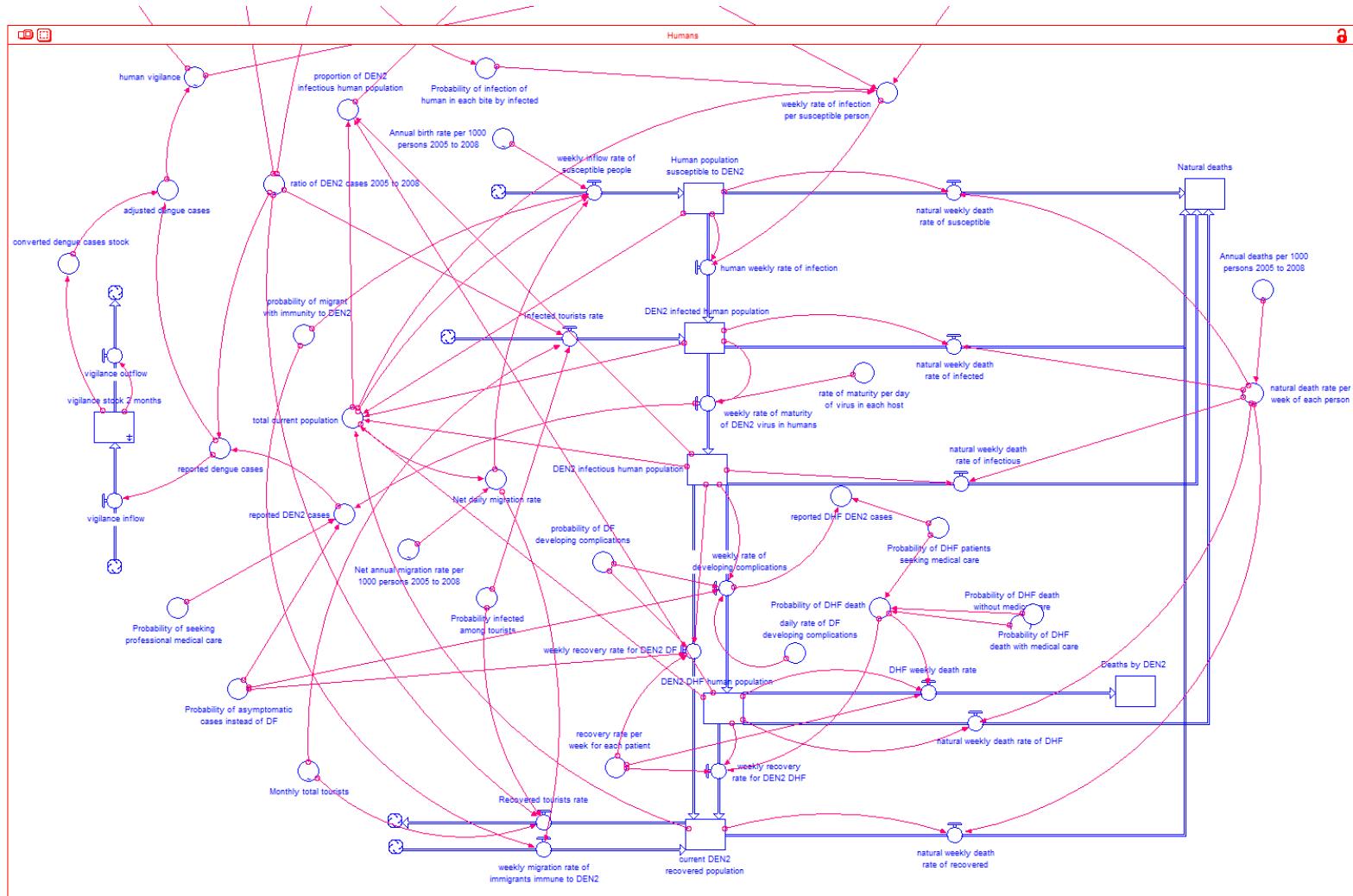
QUANTITATIVE ANALYSIS



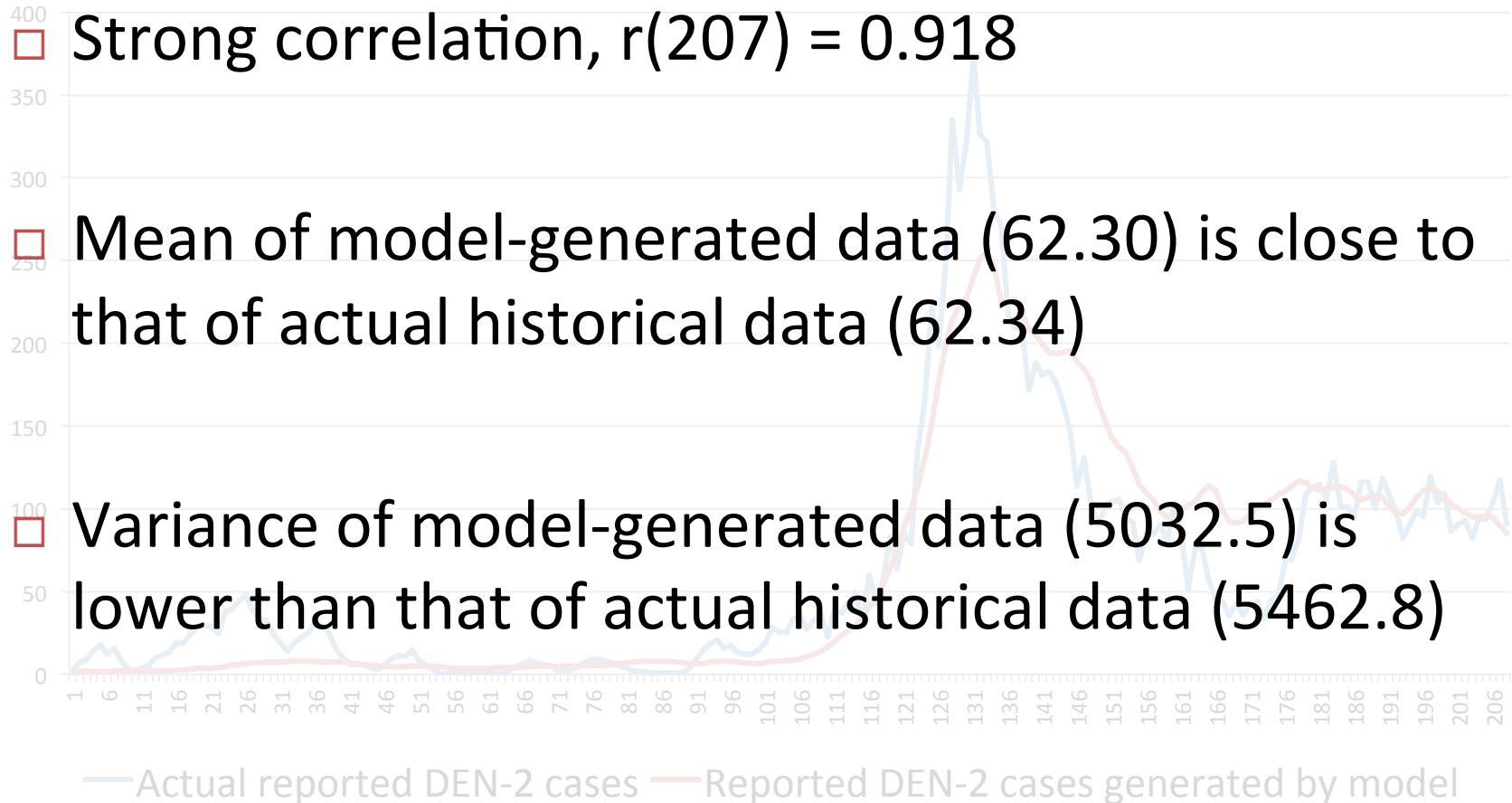
Stock-and-flow model



Stock-and-flow model



Model output

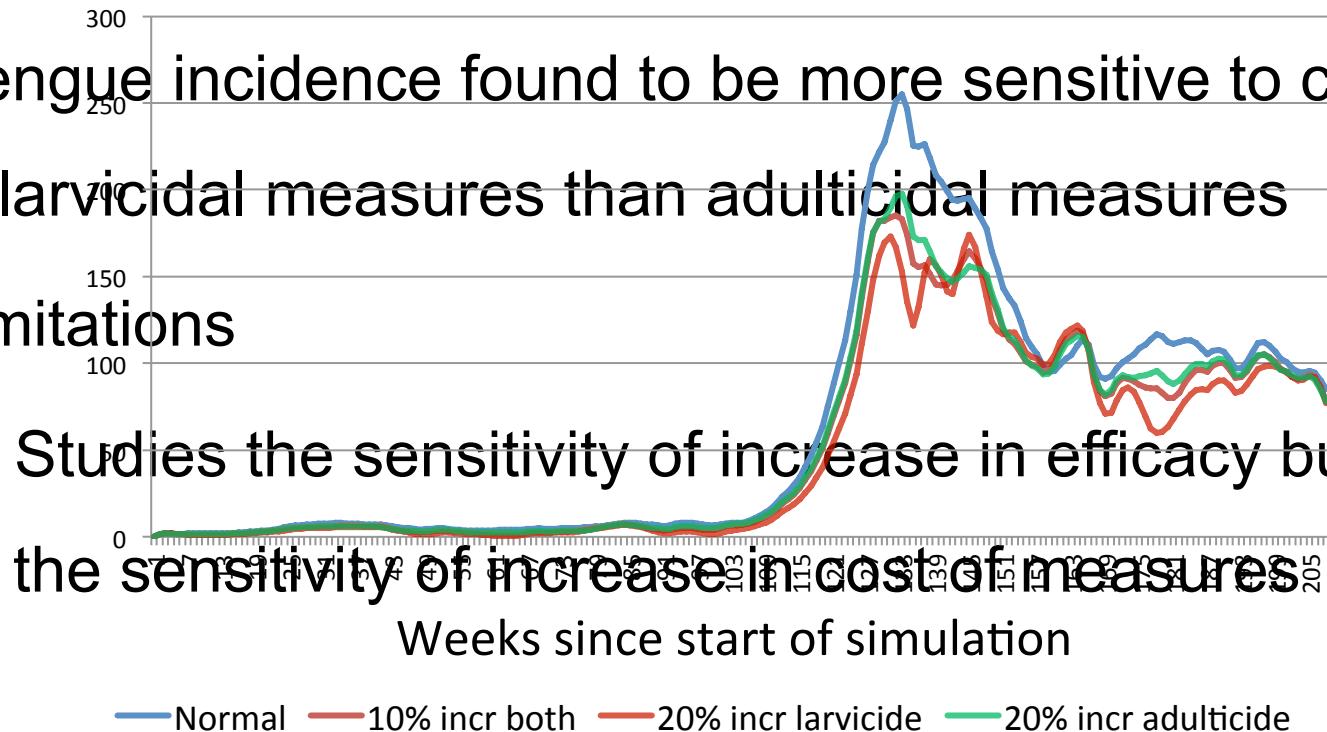


MODEL-BASED STUDIES



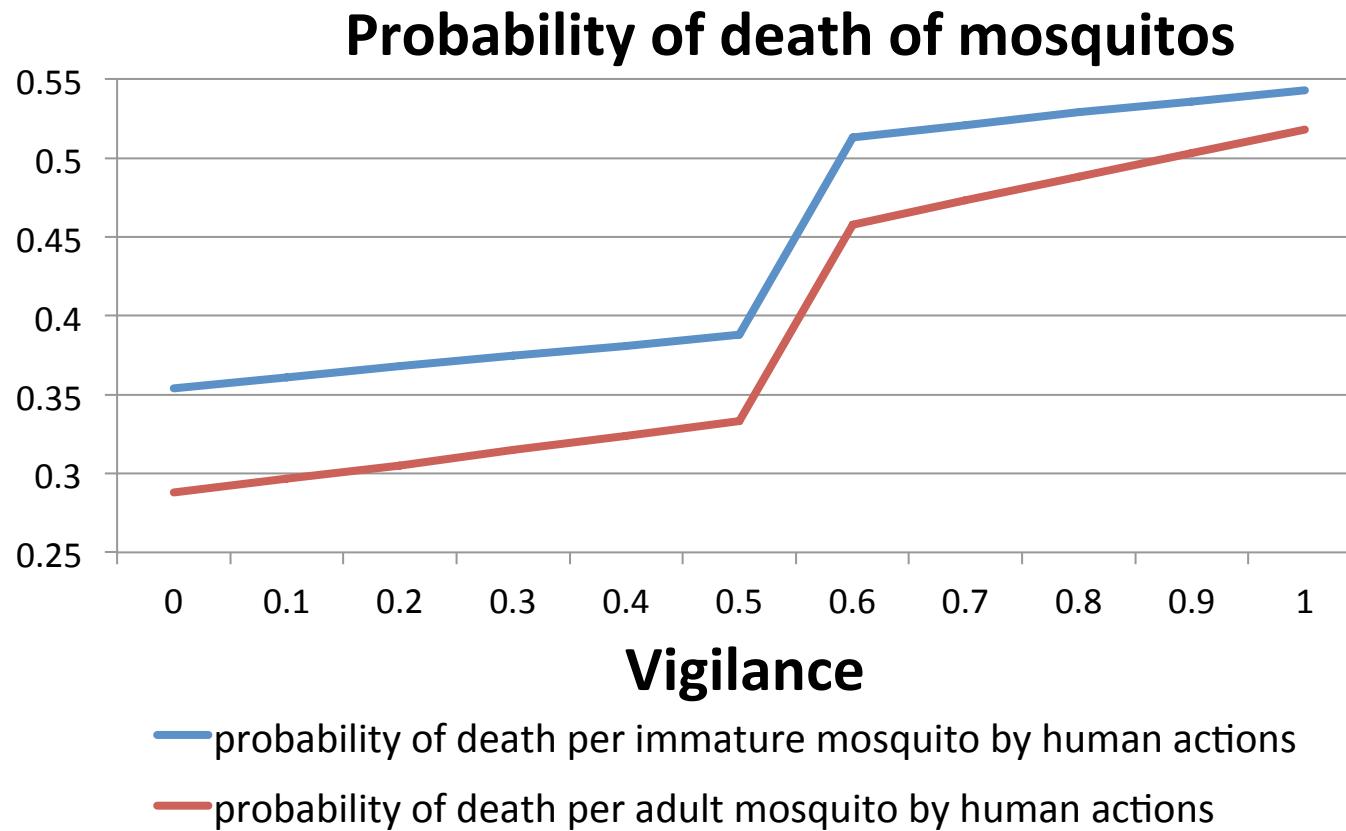
1. Comparison of control measures

- Two types of control measures targeting immature (larvicide) and adult (adulticide) mosquitoes
- Dengue incidence found to be more sensitive to changes in larvical measures than adulticidal measures
- Limitations
 - Studies the sensitivity of increase in efficacy but not the sensitivity of increase in cost of measures



2. Sustained effects of vigilance

- Vigilance represents the level of human actions



2. Sustained effects of vigilance

- Regression analysis of mosquito population:

$$y = 25821 - 3560x_0 - 944x_1 - 1608x_2 - 2120x_3 - 1876x_4$$

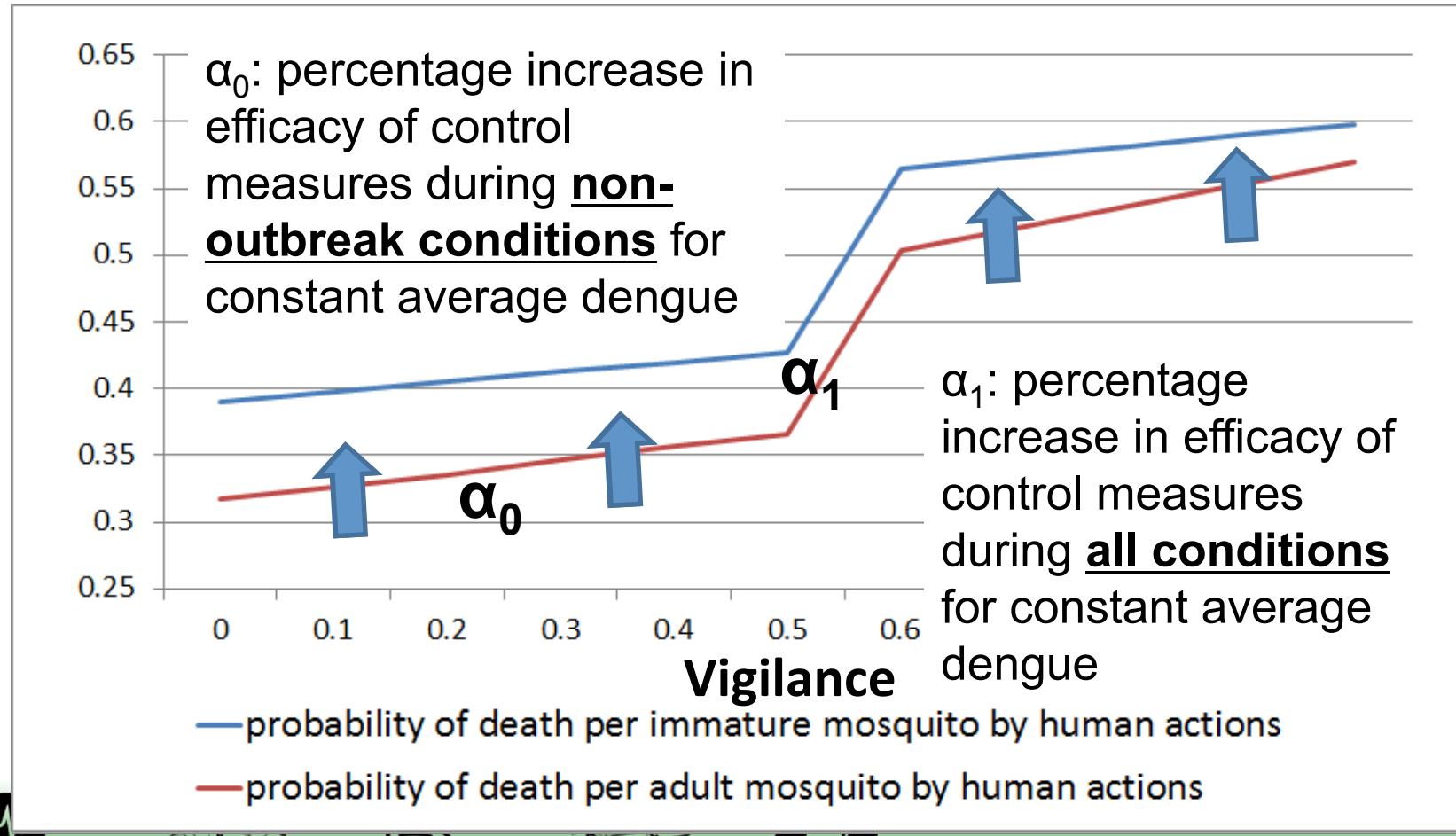
where x_i refers to vigilance value from i weeks ago

- Continuous vigilance and control is needed

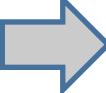


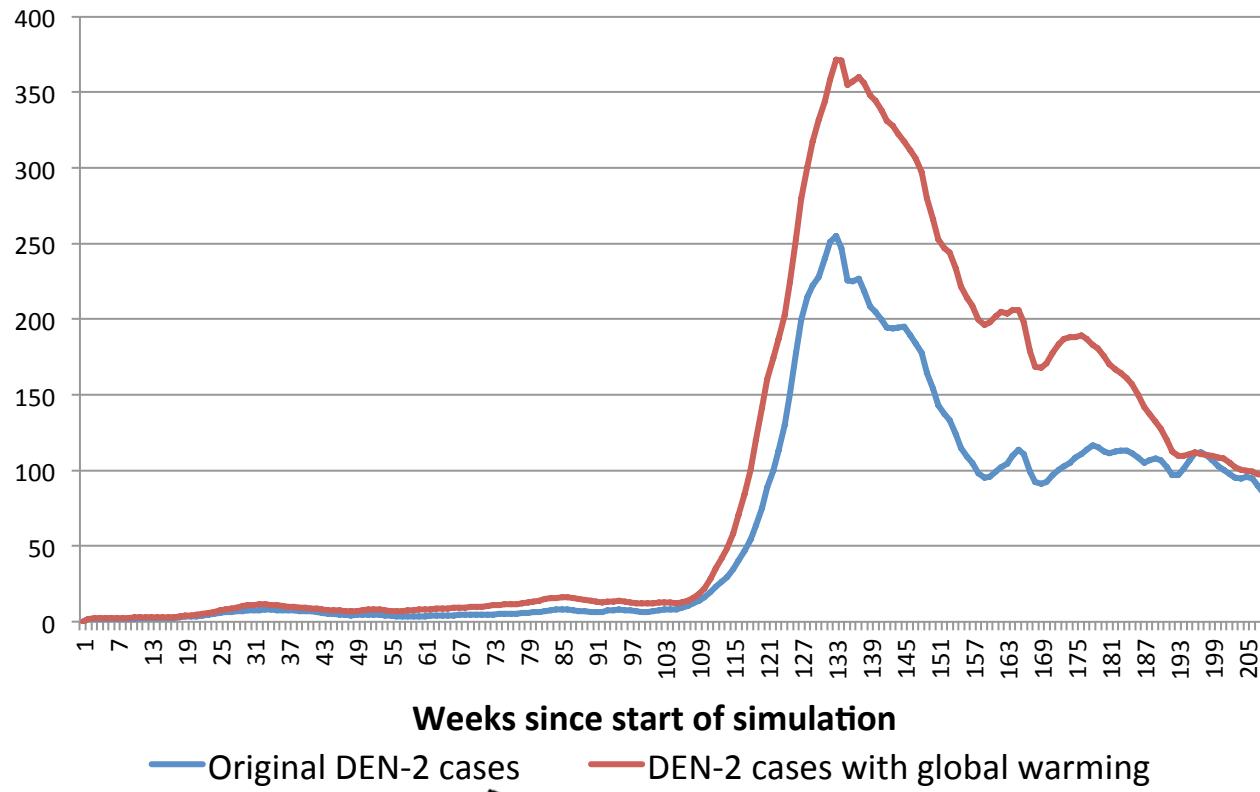
3. Scenario analysis

- Quantify impact of scenarios



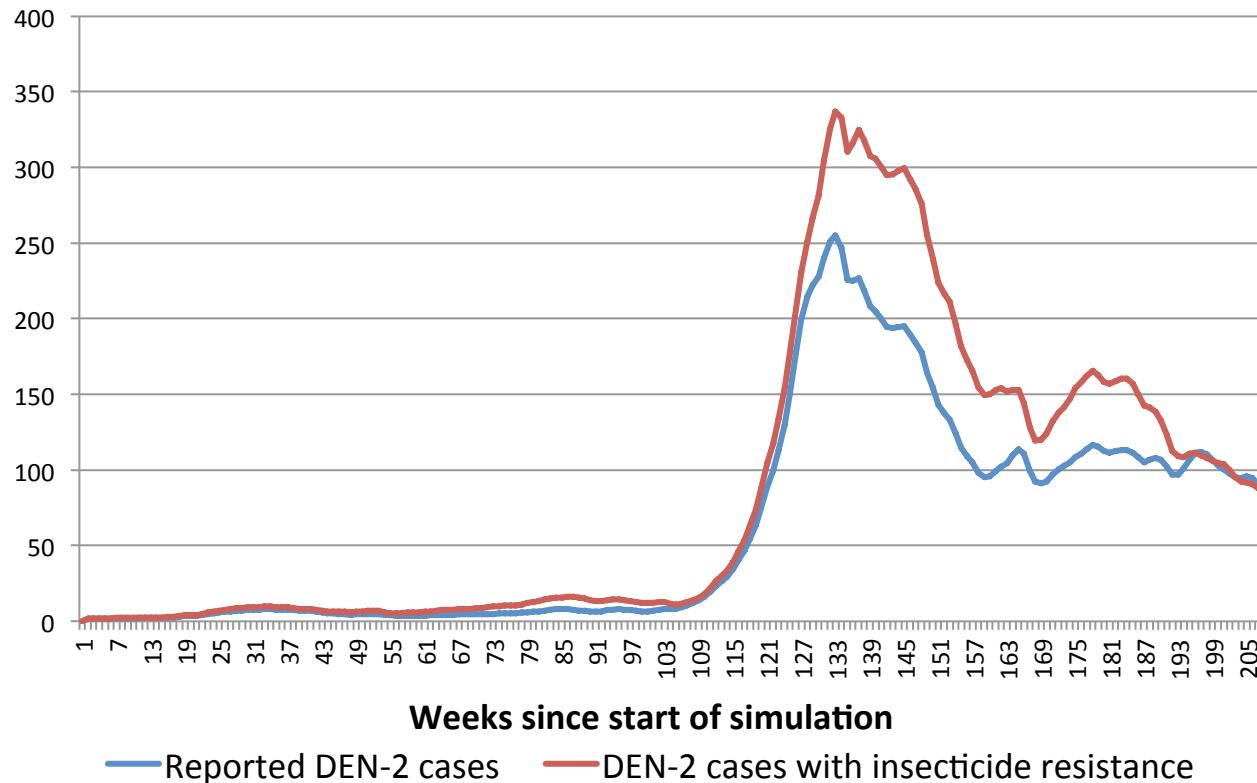
3.1. Global warming

- 1°C increase  1791 annual increase in cases

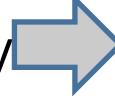


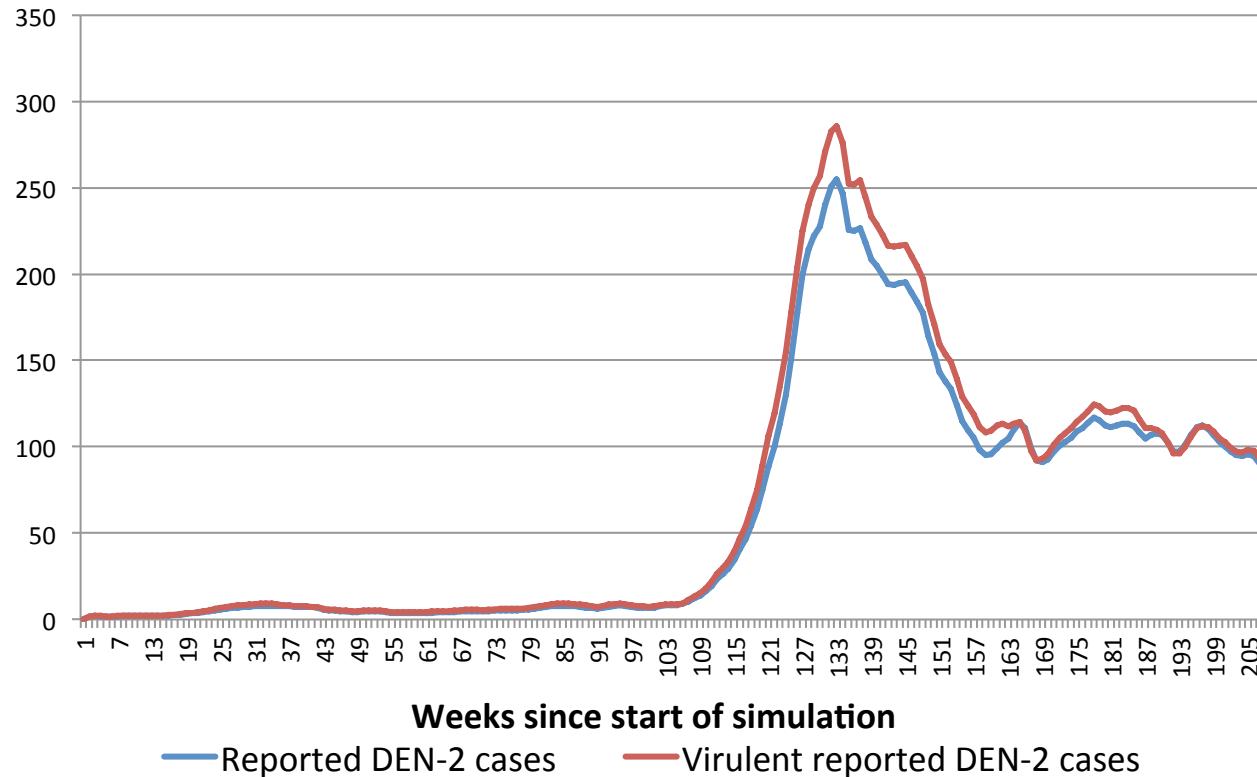
3.2. Insecticide resistance

- 10% decrease in measures  1123 annual increase in cases



3.3. Virulent dengue strain

- 5% increase in infectivity  299 annual increase in cases



Insights of scenario analysis

- Evidence that the current control measures are inadequate in facing these possible threats
- Limitations
 - Examined possible future scenarios through direct comparison instead of projection



Possible future development

- Explore interplay among all 4 serotypes of dengue
- Quantify impact on society with Disability-Adjusted Life Years (DALYs) rather than with α_0 and α_1
- Cost-benefit analysis to optimize control measures
- Extension to a predictive model analysing the risk and extent of impact of scenarios



THANK YOU

