# Modeling and Inference for Rotavirus Dynamics in Niger

(joint work with Jaewoo Park, Josh Goldstein, Matt Ferrari)

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# Outline

Rotavirus

# Rotavirus

- Rotavirus infection causes significant morbidity, mortality worldwide
- In sub-Saharan Africa, cause of diarrheal disease often unknown due to lack of infrastructure
- Uncertainty about the underlying transmission dynamics
- Our Goal:
  - Estimate burden of rotavirus in the Maradi region of Niger
  - Predict impact of vaccination on rotavirus burden
- Methods:
  - Compare several compartmental SIR type models.
  - Account for model uncertainty via Bayesian model averaging (BMA).

# Two Sources of Rotavirus Data

- Surveillance data collected over two years (12/2009 - 4/2011) from hospitals and health centers
  - 9,600 children $\leq$ 5 years presenting with severe diarrhea
  - For each child: Dates of consultation, results of a rapid rotavirus diagnostic test (30% test positive)
  - A subset (378) of cases are also genotyped
- Cluster survey of households with children $\leq$ 5
  - Hospital surveillance data can miss a majority of cases
  - Use cluster survey to estimate reporting rates (42.9% sought care at a hospital or health center).

# Vaccination

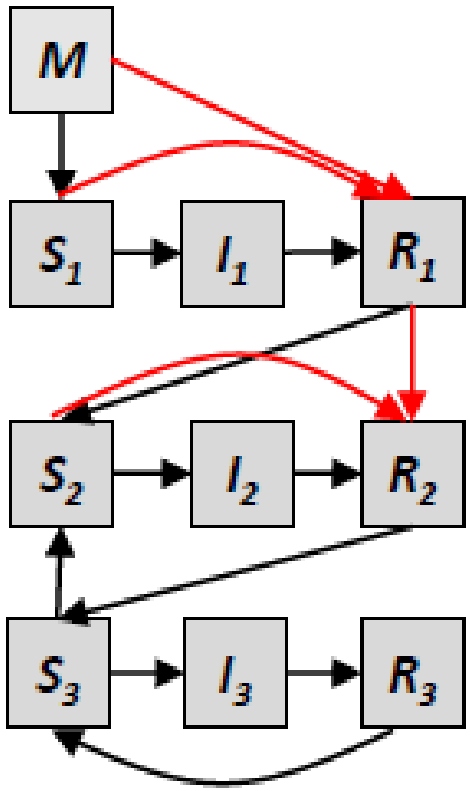
- Two dose strategy: 2 months, 4 months of age
- Assume vaccination confers same level of protection as an infection.
- Both short-term (5 years) and long-term (20 years) effects are investigated.

# SIR Compartmental Models

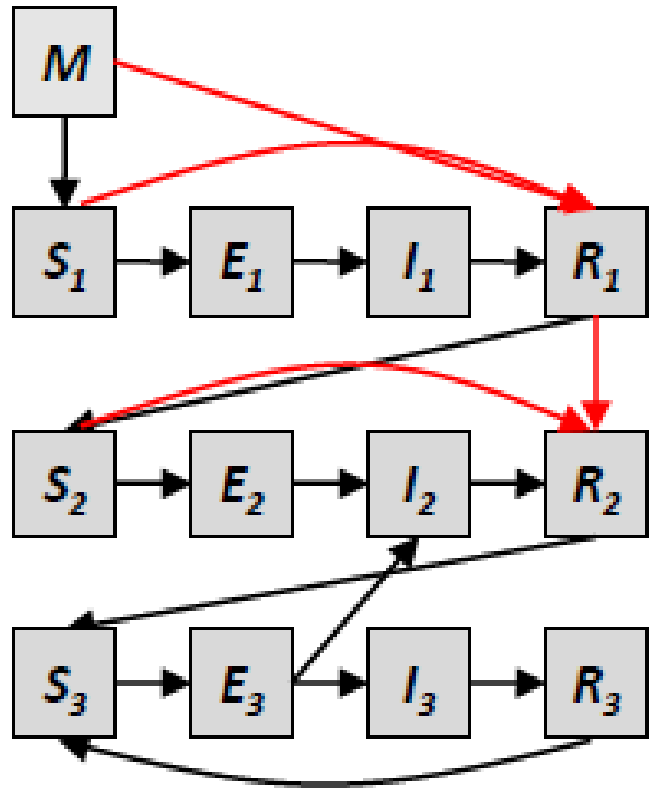
- We consider 5 different SIR models (Pitzer et al., 2012)
- Notation:
  - (M) the number of individuals in maternal immunity
  - (S) the number of susceptible individuals
  - (E) the number of individuals in incubation period
  - (I) the number of infected individuals
  - (R) the number of recovered individuals

# Model Examples

B




C



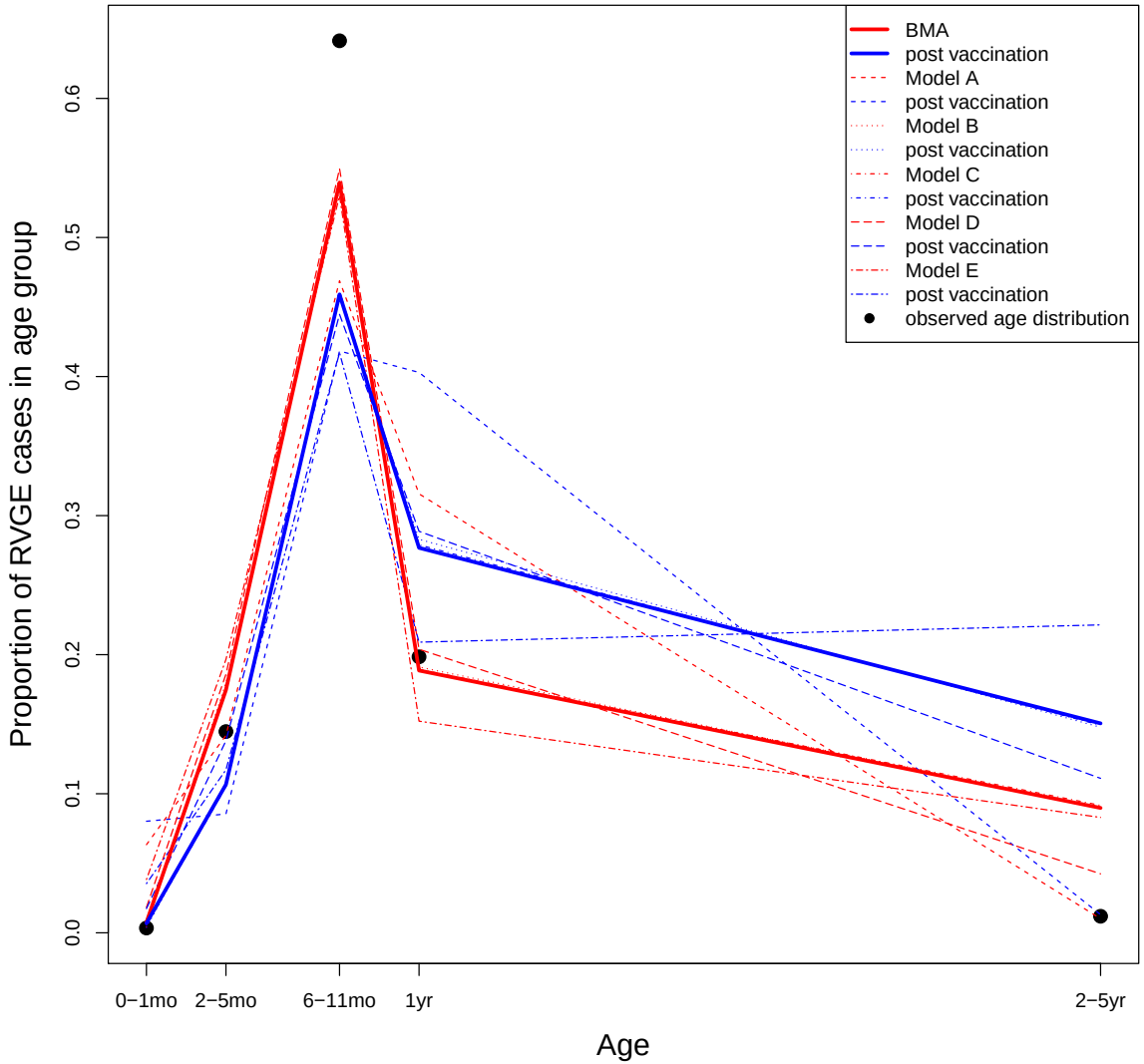
# Model Examples

- Models differ by characteristics such as:
  - Whether they track severe and mild cases separately
  - Whether they allow for successive infections
  - Whether they allow for incubation period
  - How immunity is granted

# Inference and Model Details

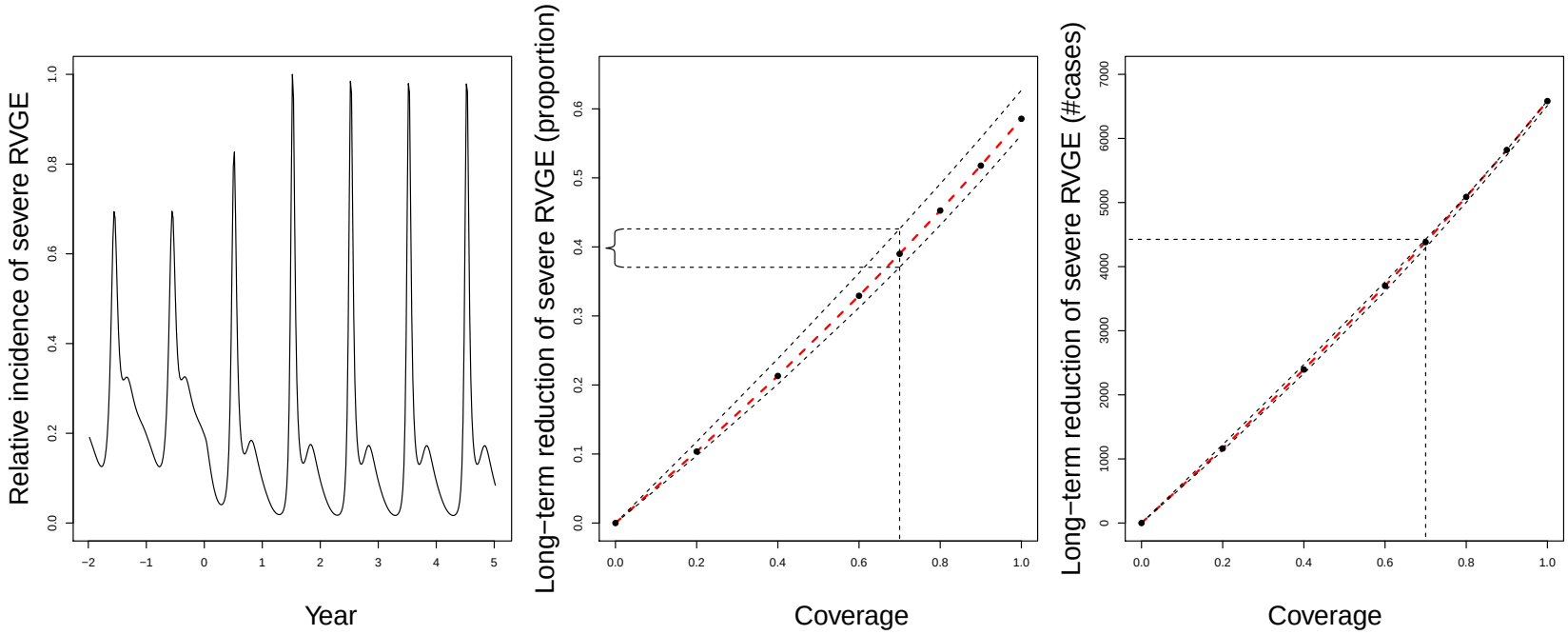
- Bayesian inference via Markov chain Monte Carlo
  - Periodic solution for the disease dynamics is required for likelihood evaluation
- Dynamics Accounting for Vaccination
  - Given estimated model parameters, dynamic models integrated forward to steady state solution.
  - Then, the dynamics are modified to account for vaccination.
- BMA (Bates and Granger, 1969; Hoeting et al., 1999)
  - Posterior model probability (PMP) measures how well each model is supported.
  - Combining information across models

# Distribution of Cases Across Age Groups




- Vaccination causes a noticeable shift in the age distribution

# Model-averaged predicted vaccine impact




- Over the short term (Left), models predict an overall decline in total burden, but an increase in the magnitude of peak incidence.
- For a fixed (70%) level of coverage, we predict 38.9% reduction of severe rotavirus (99%CI : (37.1%; 42.6%)) over the long-term (Middle)

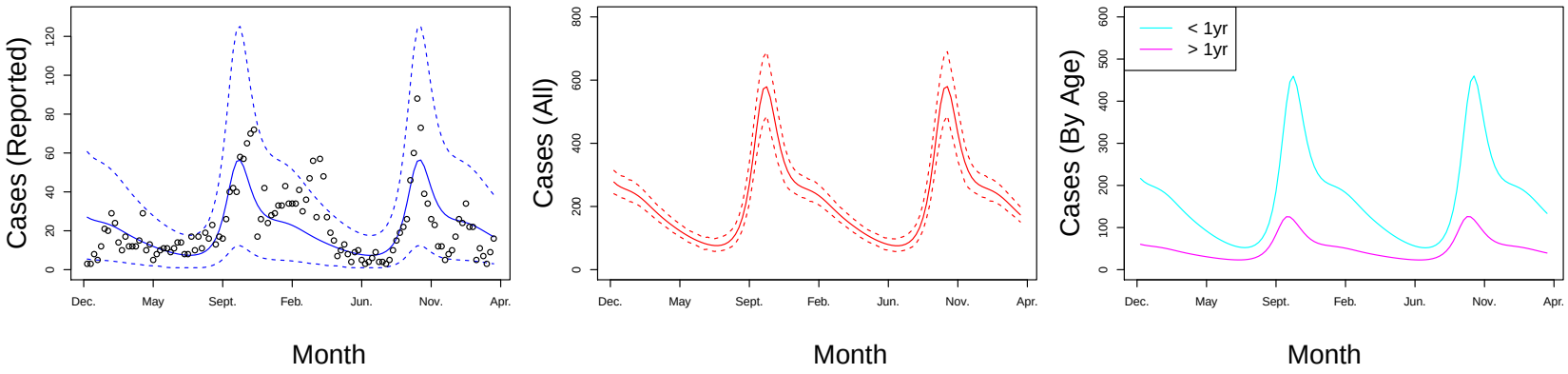
# Pre-vaccination

**Model Comparison Summary**

| Model | Probability | $R_0$ | Burden |
|---|---|---|---|
| A | 0 | 30.7 (25.8,34.3) | 9.2 (8.1,10.1) |
| B | 0.01 | 13.9 (12.7,15.4) | 3.5 (3.1,3.8) |
| C | 0.92 | 13.4 (11.7,15.3) | 3.5 (3.1,3.9) |
| D | 0.03 | 11.2 (9.4,12.7) | 3.6 (3.2,4.1) |
| E | 0.04 | 10.3 (9.5,12.6) | 3.2 (2.9,3.5) |
| BMA | | 13.4 (10.3,15.4) | 3.5 (2.9,4.2) |

- Model C performs the best, Model A performs significantly worse.
- Estimates of burden and basic reproductive ratio ($R_0$) are significantly larger for Model A.

# Model-averaged (BMA) burden estimates




- Models successfully capture the observed dynamics (dots). Seasonal effects explain observed double incidence peak.
- Models predict a steep decline in cases in children under 1y of age following the epidemic peak.

# Conclusions

- We develop flexible models that allow for a variety of different transmission dynamics for rotavirus
- BMA approach can account for uncertainty in the underlying dynamics.
- We can predict short-term/long-term reduction in rotavirus due to vaccination.
- Evidence that human activity is the primary vector of transmission.
  - The peak transmission estimated with a maximum in early March.
  - Urban population density is at its maximum due to seasonal rural-urban migration (Bharti et al., 2011)

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