Centers for Disease Control and Prevention

Advances in epidemic forecasting & implications for vaccination

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Fondation Mérieux

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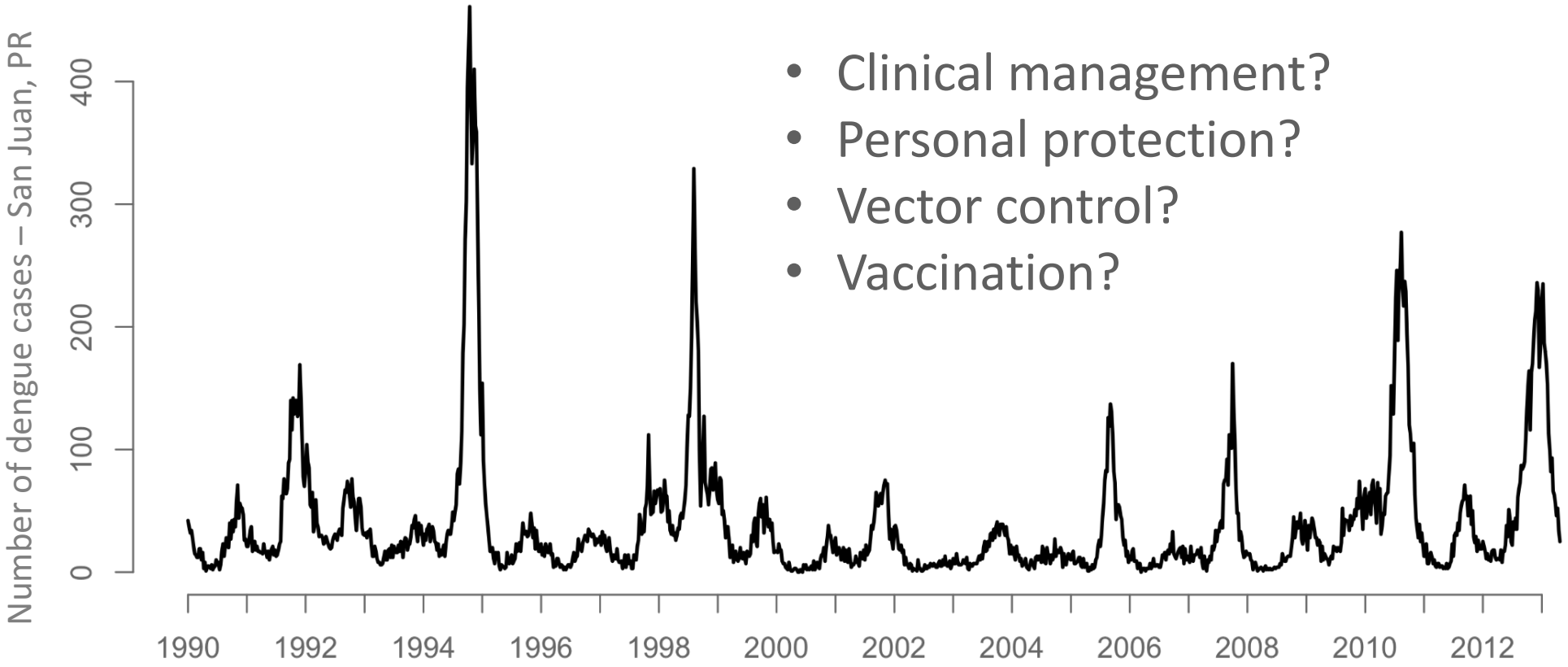
"All decisions are made on the basis of models. Most models are in our heads. Mental models are not true and accurate images of our surroundings, but are only sets of assumptions and observations gained from experiences ... [Quantitative] models can compensate for weaknesses in mental models."

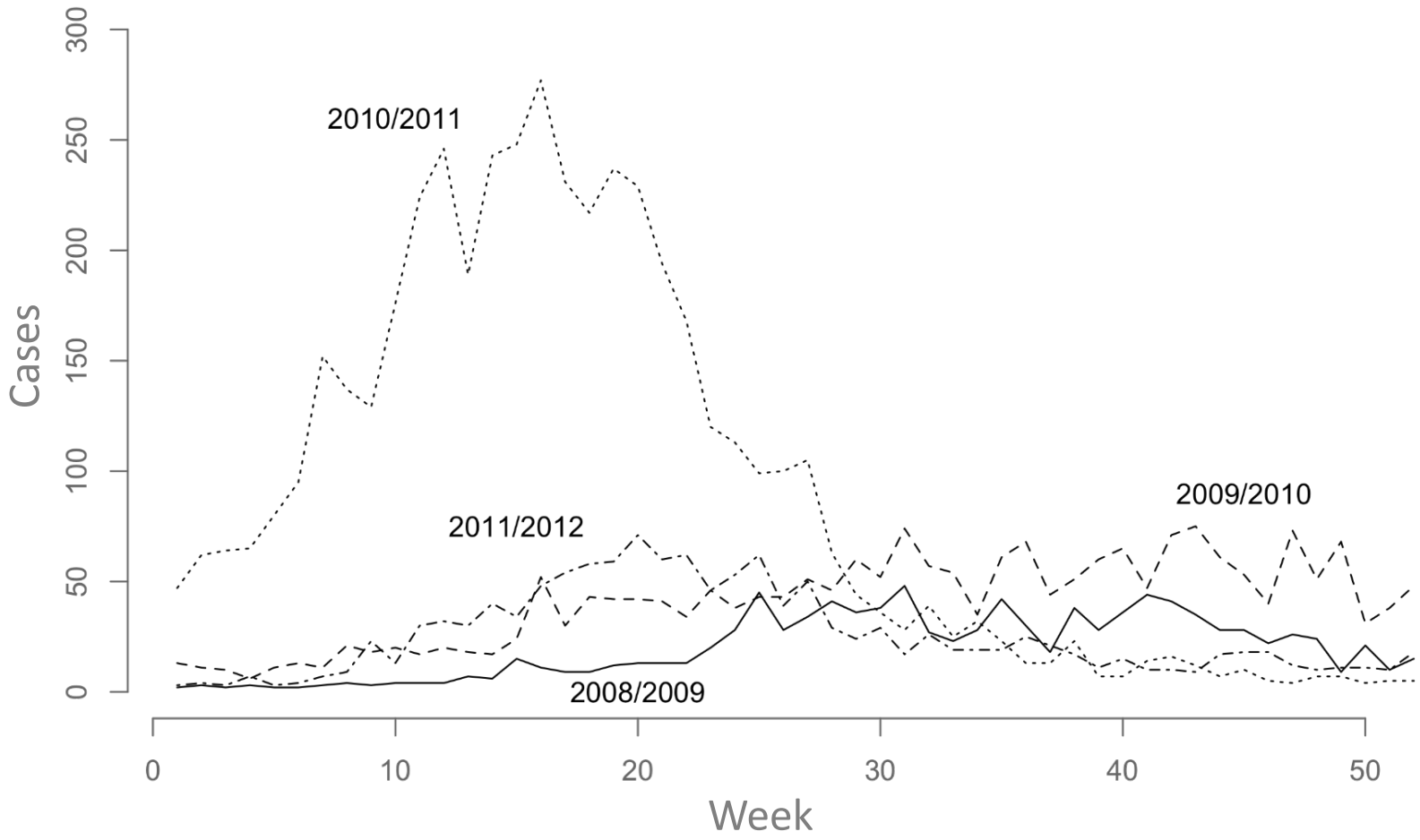
- Jay Forrester

Seasonal diseases

Prioritization, timing, and scale of interventions



- Clinical management?
- Personal protection?
- Vector control?
- Vaccination?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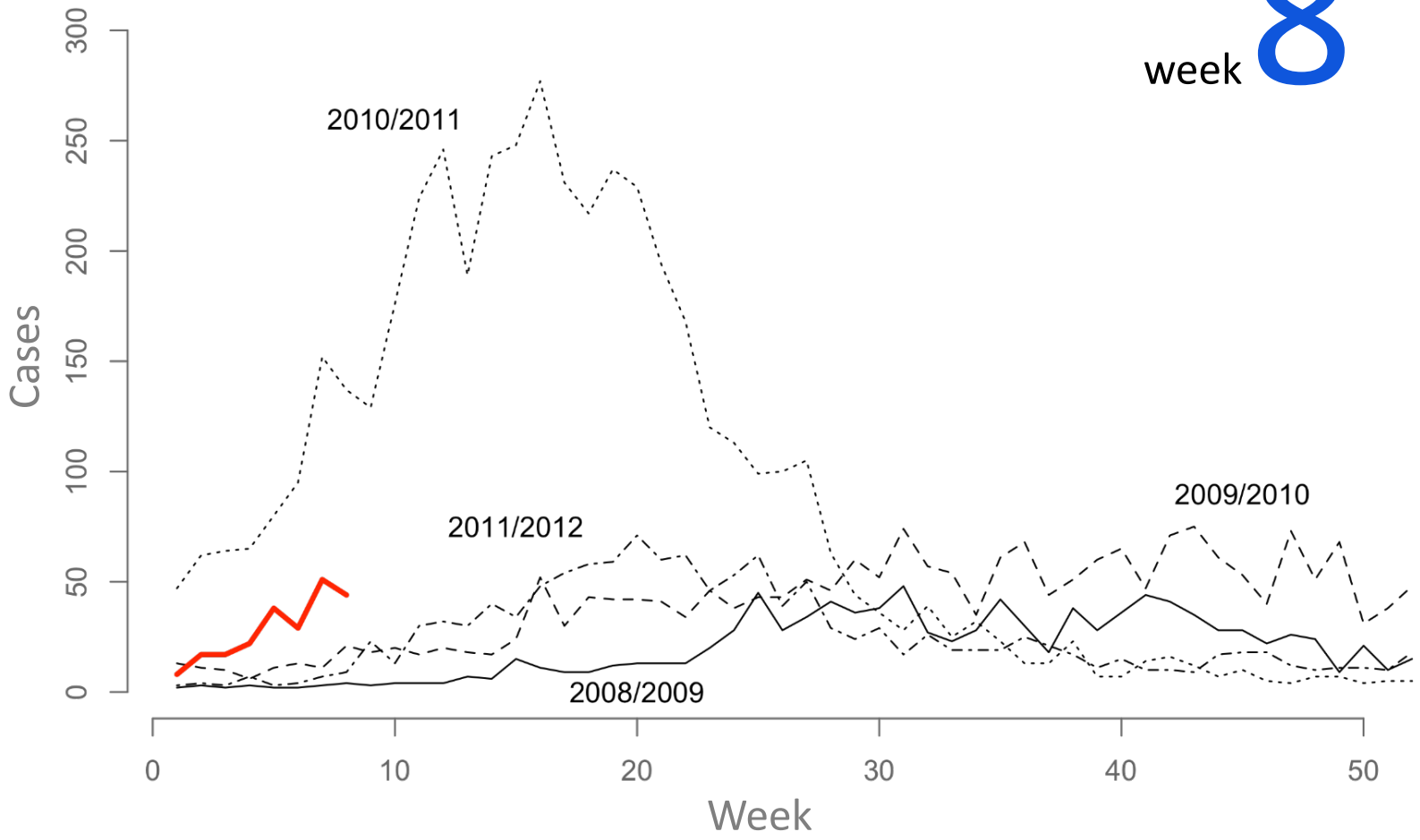
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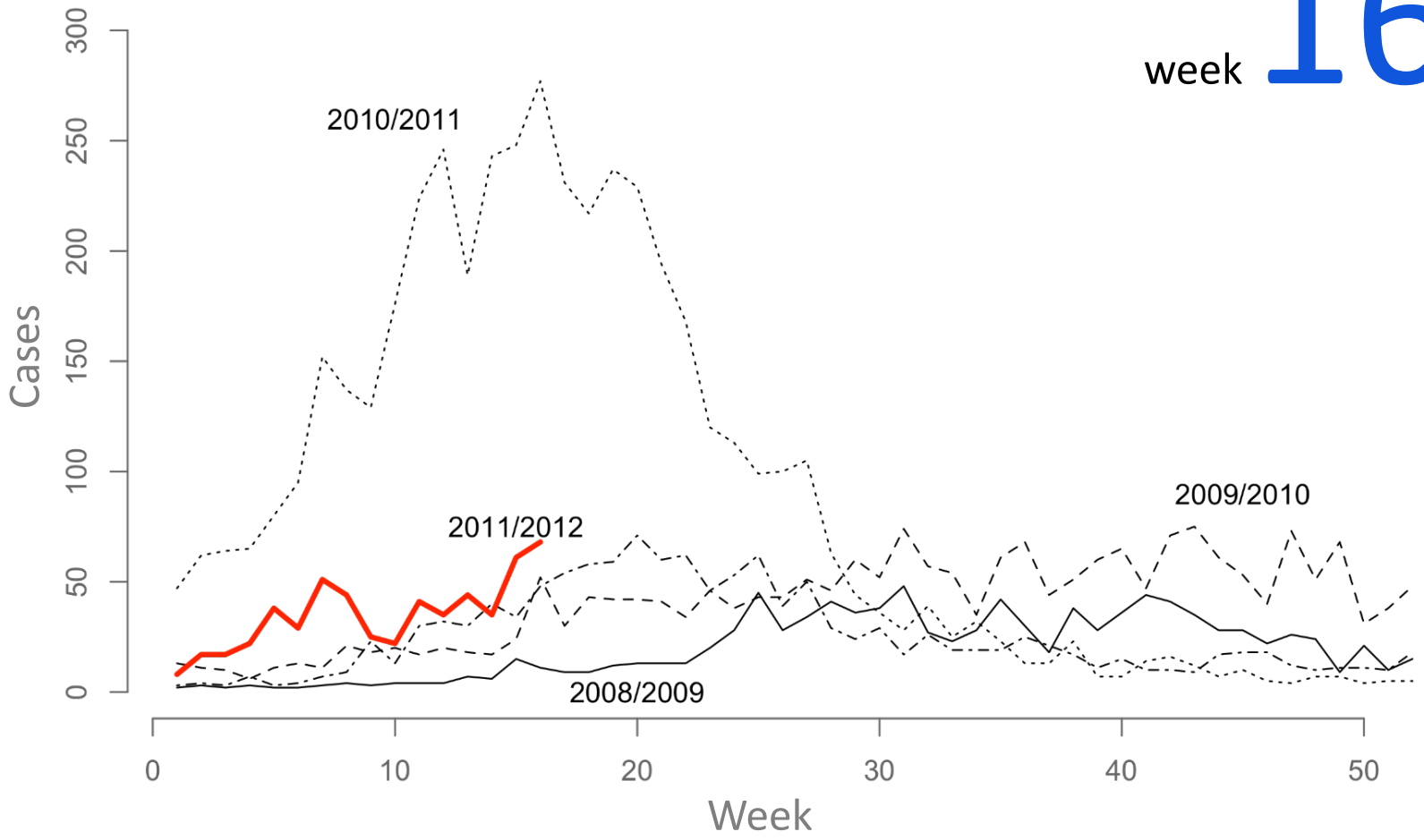
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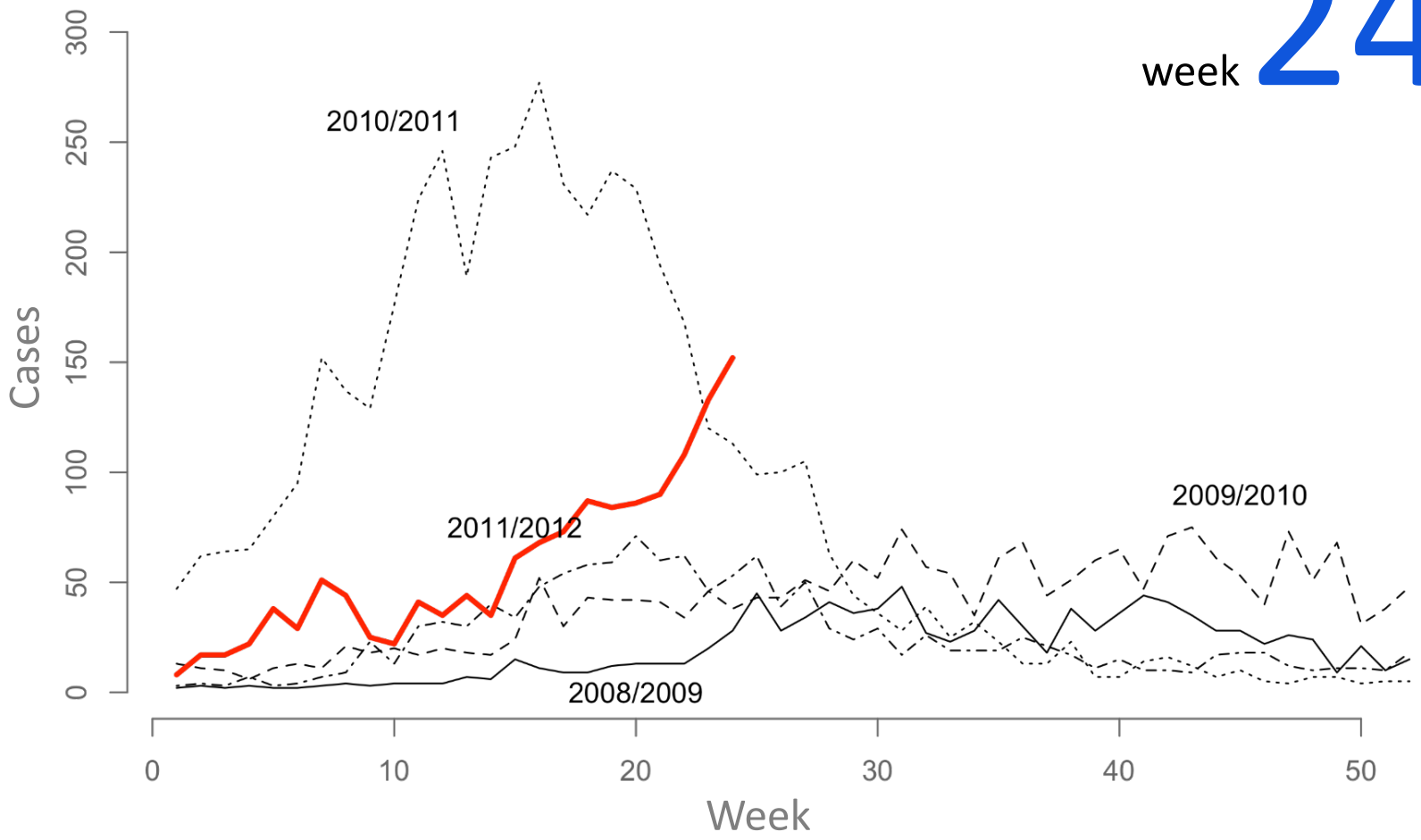
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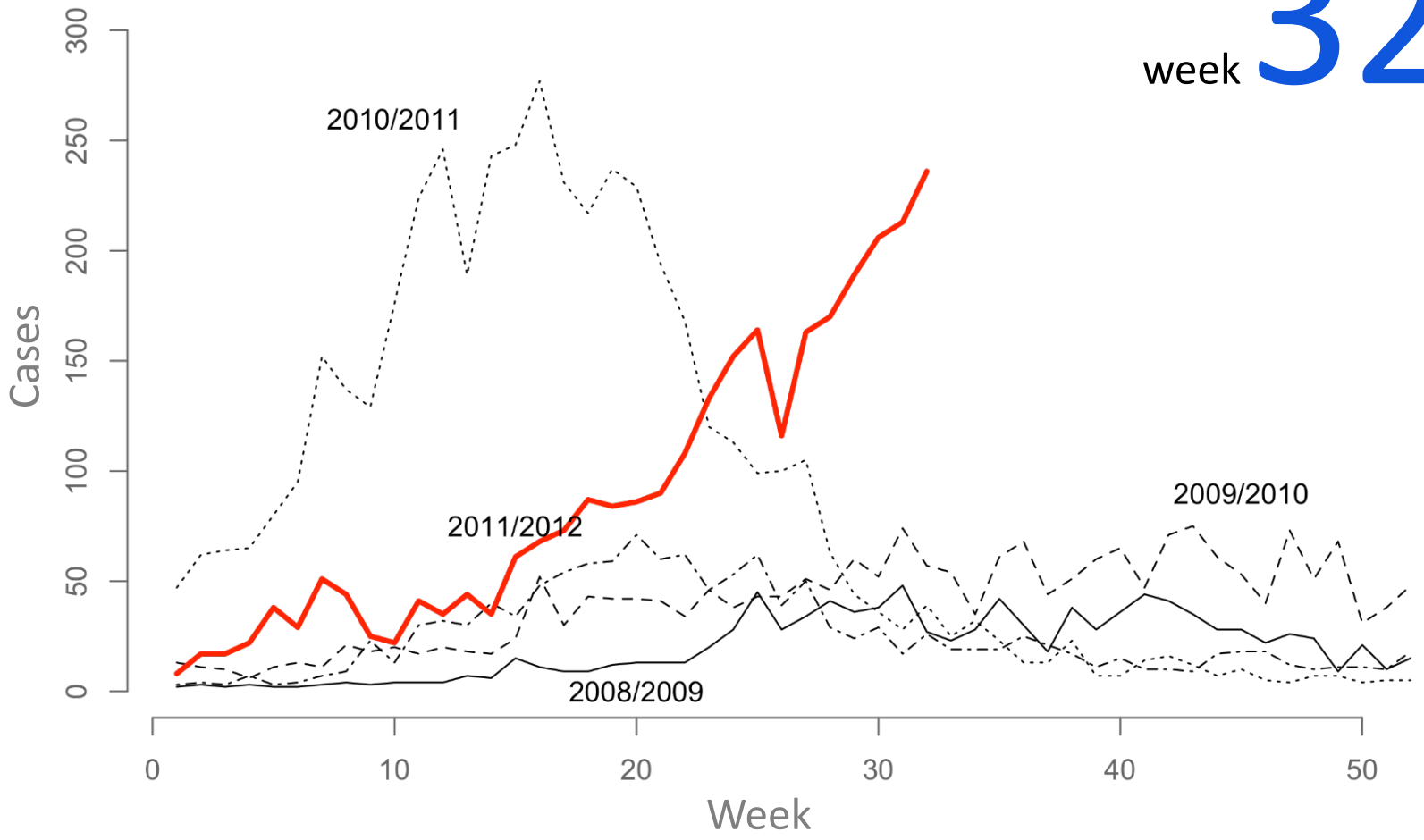
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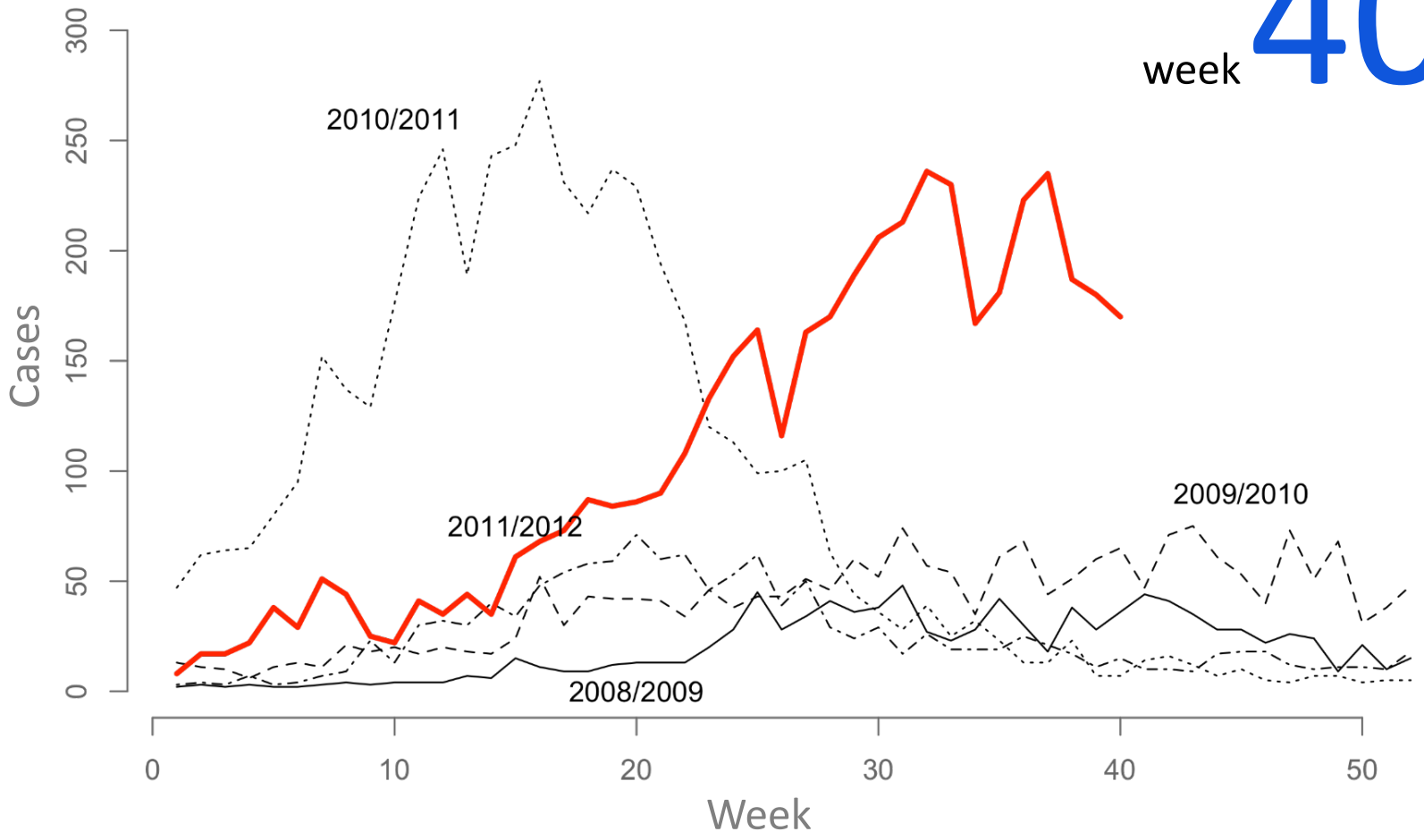
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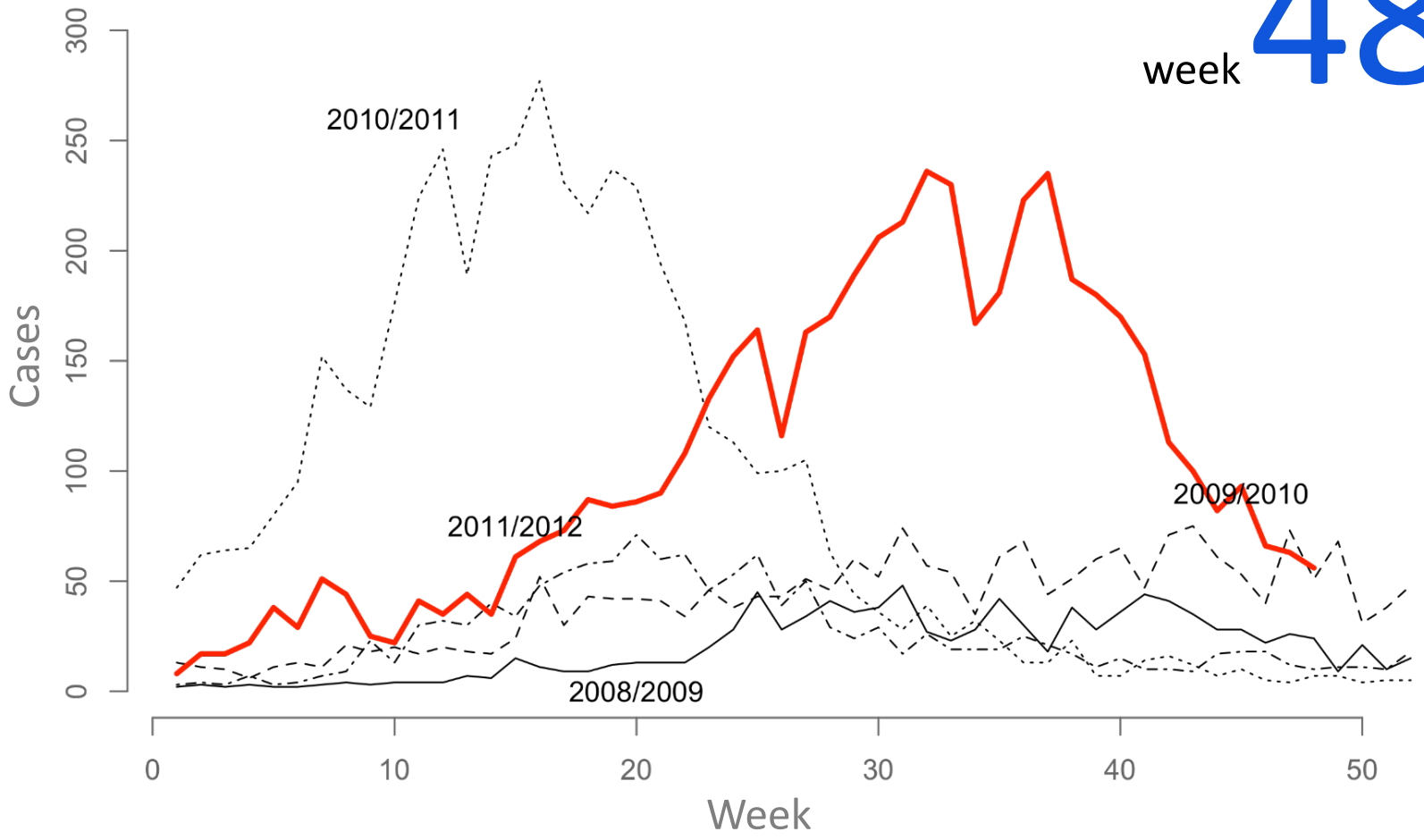
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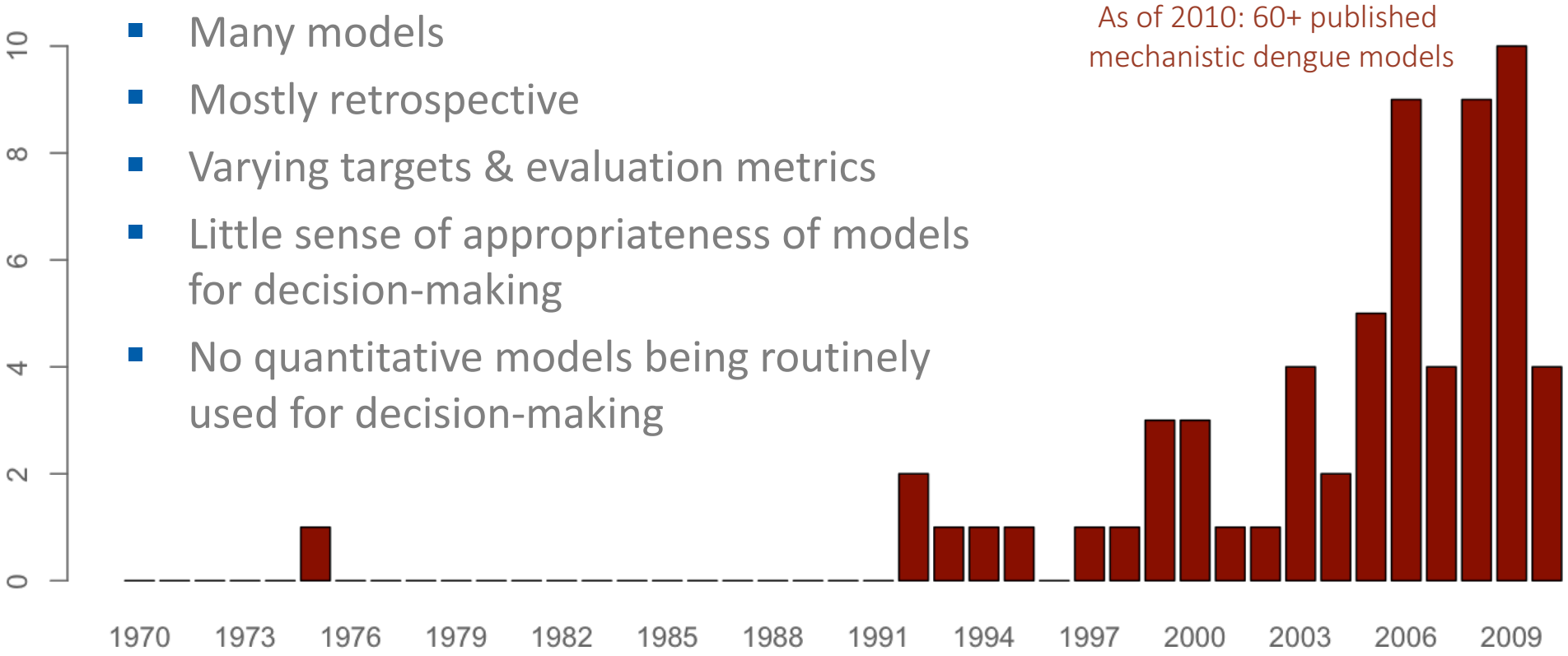
The state of dengue & influenza forecasting

- Many models
- Mostly retrospective
- Varying targets & evaluation metrics
- Little sense of appropriateness of models for decision-making
- No quantitative models being routinely used for decision-making



Reiner & Perkins et al. J R Soc Interface 2013, Chretien et al. PLOS ONE 2014

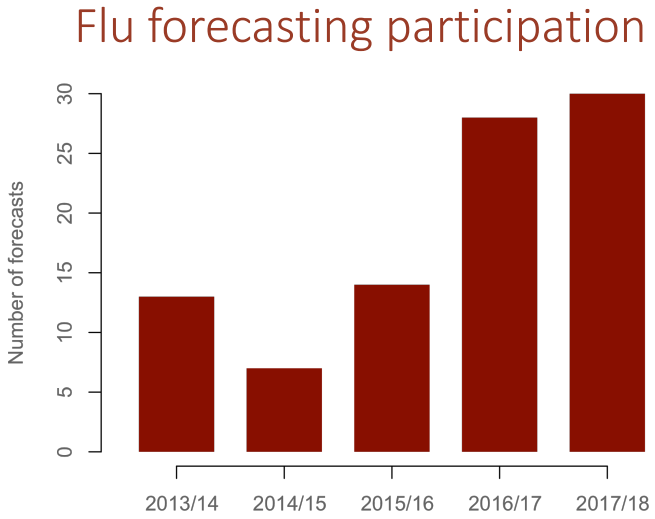
CDC Epidemic Prediction Initiative

- Started in 2014
- Objectives:
  - Connect forecasting research to decision making needs
  - Facilitate forecasting research
  - Evaluate forecast skill
  - Operationalize forecasting
- Contributors: Matthew Biggerstaff, Craig McGowan, Juan Sanchez Montalvo, Luis Mier-y-Teran, participants and collaborating organizations
- Funding: CDC Office of Public Health Preparedness & Response

predict.phiresearchlab.org

Open collaborative forecasting projects

- Influenza (2013-present, CDC)
  - Real-time forecasting of ILINet (national, regional, state) and hospitalizations
  - Growing network of public health, academics, and private companies
- Dengue (2015, US Gov PPFST* Working Group)
  - Retrospective forecasts for 8 dengue seasons in Puerto Rico & Peru
  - 16 participating teams

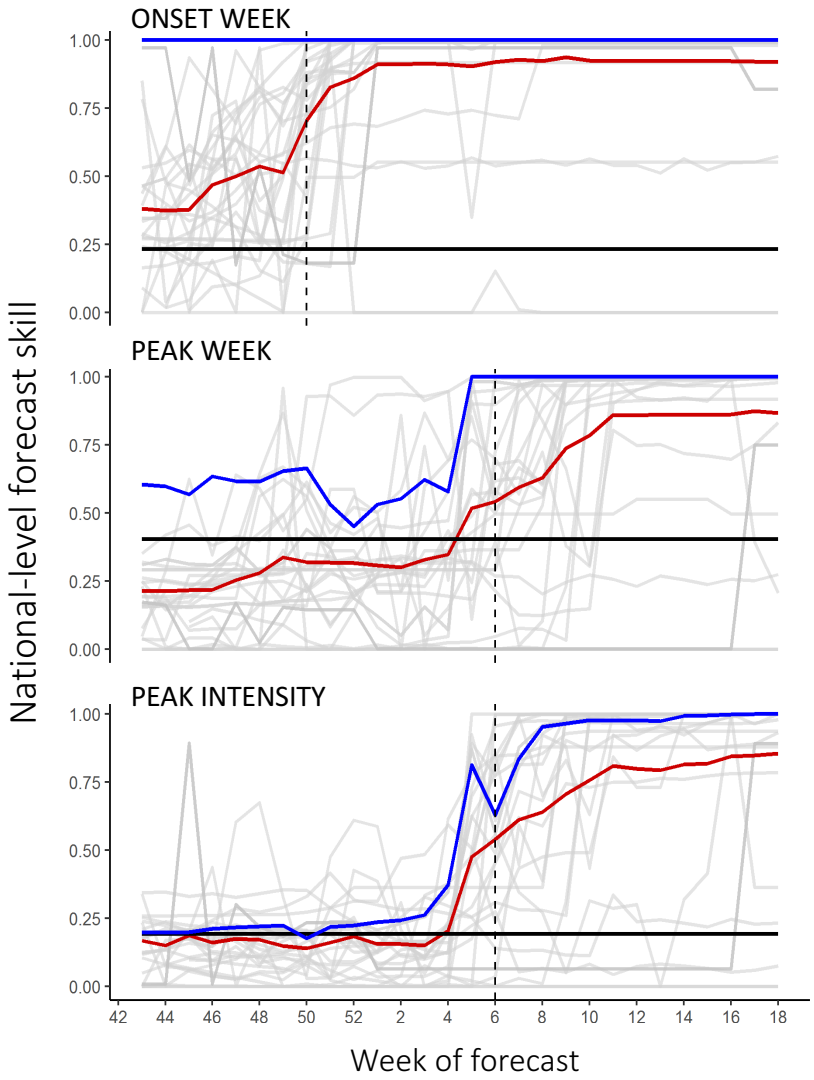


*Pandemic Prediction and Forecasting Science and Technology Working Group

predict.phiresearchlab.org, Biggerstaff et al. BMC Infect Dis. 2016

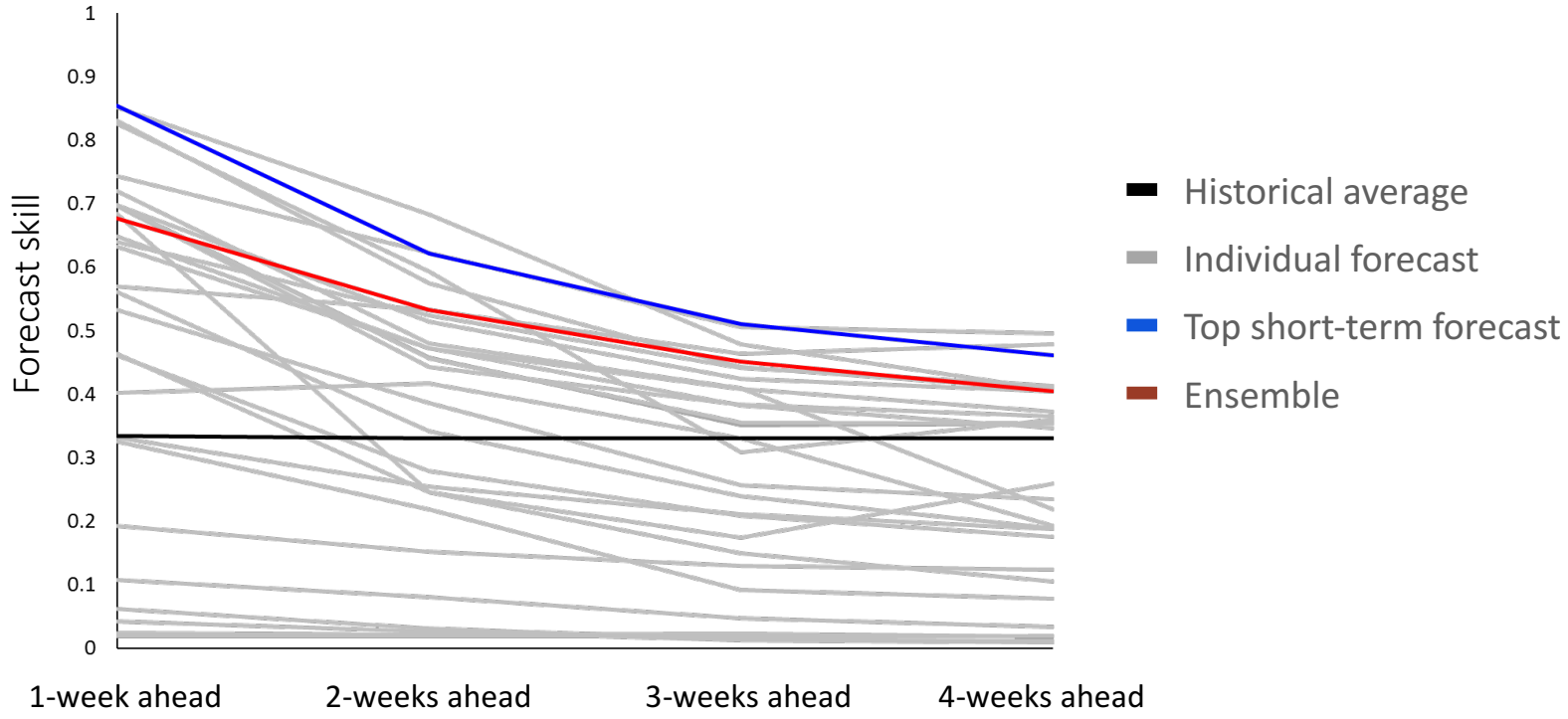
US seasonal influenza forecasts 2016/17

- Individual forecasts often outperform the historical average
- Ensemble forecasts provide consistent improved performance across locations and time



- Historical average
- Individual forecast
- Top forecast for target
- Ensemble

Short-term forecasts



Forecast assessment

- 100,000+ forecasts have been quantitatively evaluated:
  - 2 pathogens
  - 13 locations
  - 7 seasons
- The importance of data and model types remains unclear.
- Early season forecasting remains challenge.
- **Current ensemble forecasts consistently outperform historical expectations.**
- New models, including improved ensembles, are being developed and tested all the time.

Importance to vaccination

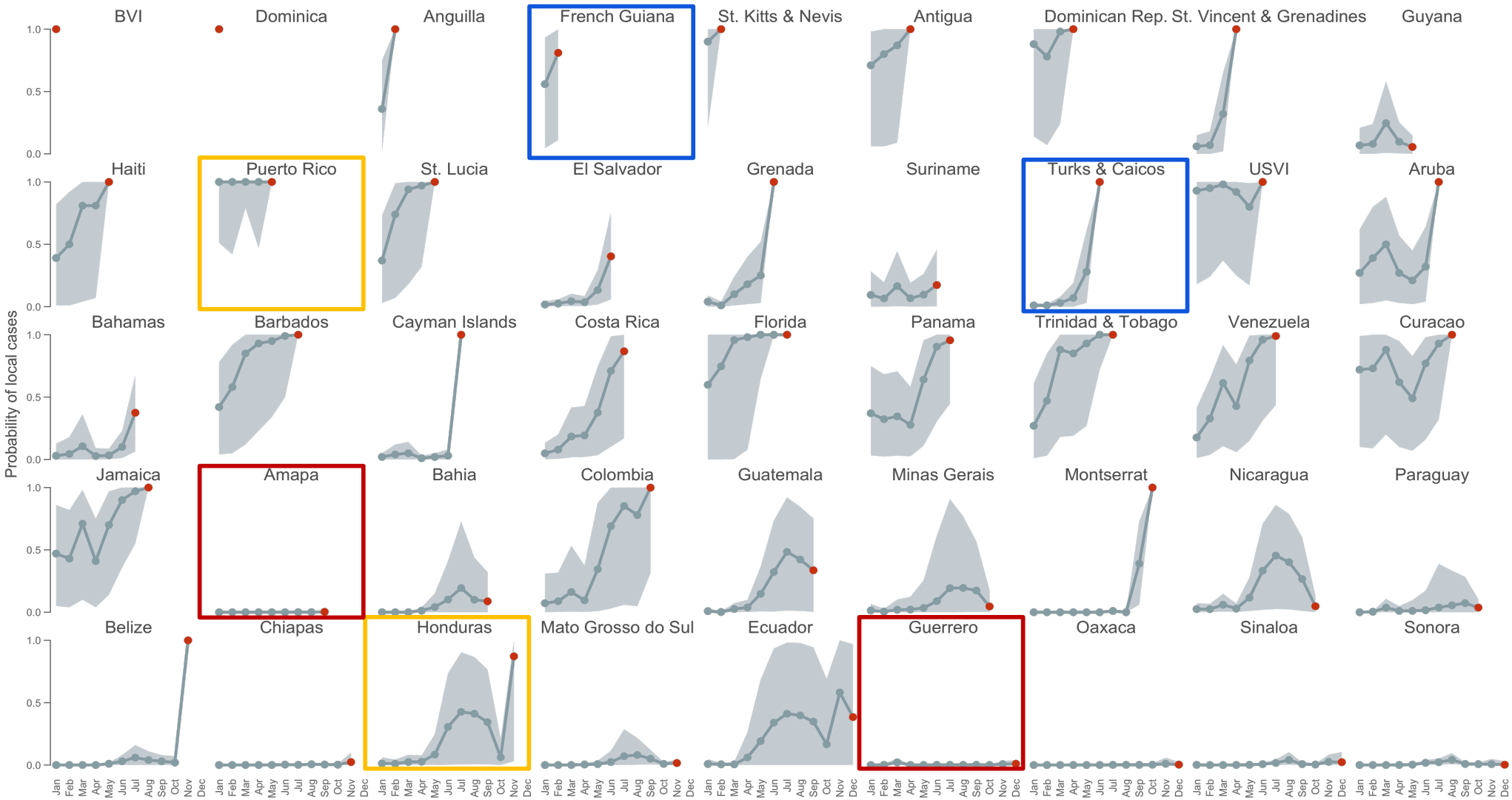
- Can real-time disease forecasts drive vaccine use?
- When should the most resources be directed to vaccination versus treatment?
- Is there time to develop a different vaccine?
- What is the likely impact of vaccination on the epidemic trajectory (*a priori*)?
- What was the impact of vaccination on the epidemic (*a posteriori*)?

Emerging pathogens

Risk assessment & intervention planning

- Where will it go?
- When will it arrive?
- How bad will it be?
- How can it be prevented or controlled?

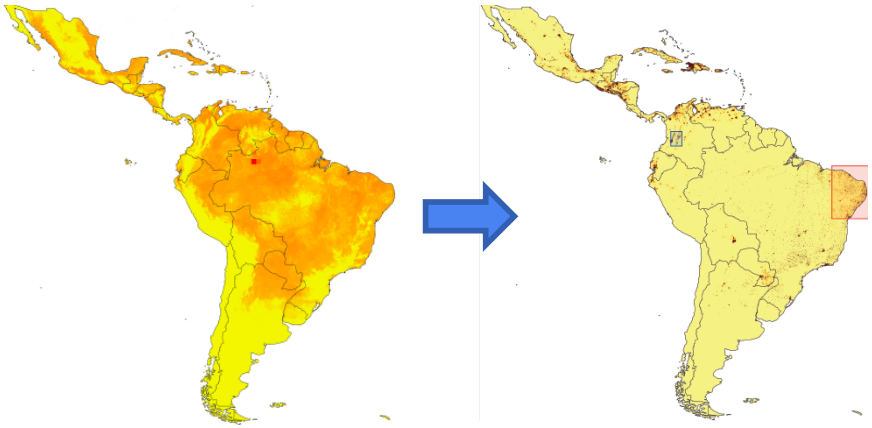
Johansson et al. PLOS ONE 2014, www.cdc.gov/chikungunya/modeling



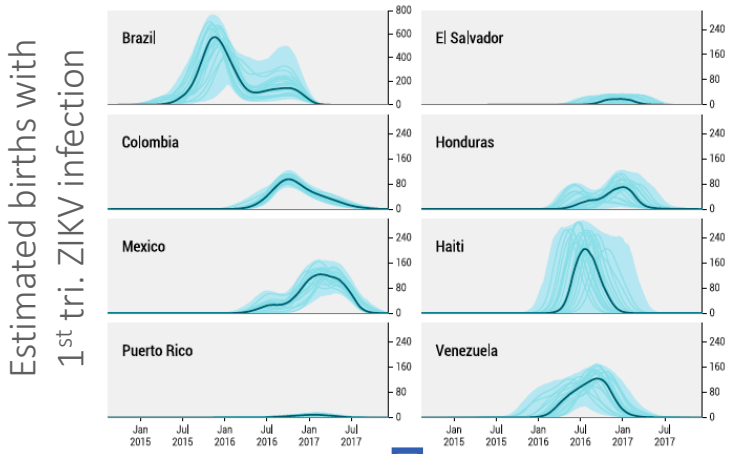
Johansson et al. PLOS ONE 2014, www.cdc.gov/chikungunya/modeling

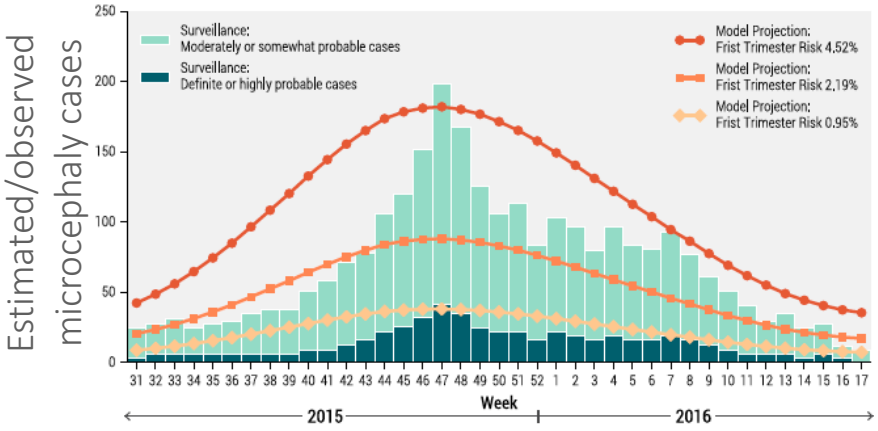
Impact assessment

Estimated ZIKV infection risk



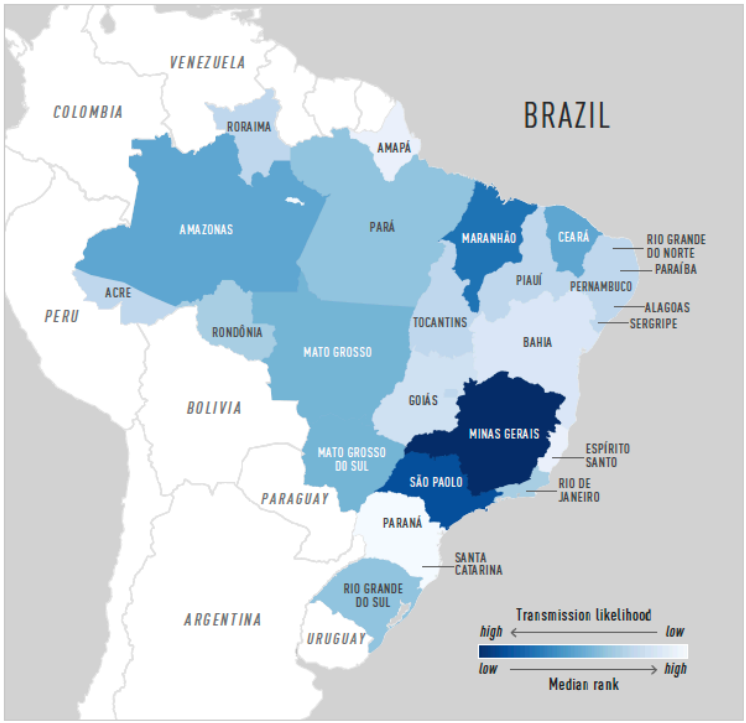
Estimated infections in pregnant women

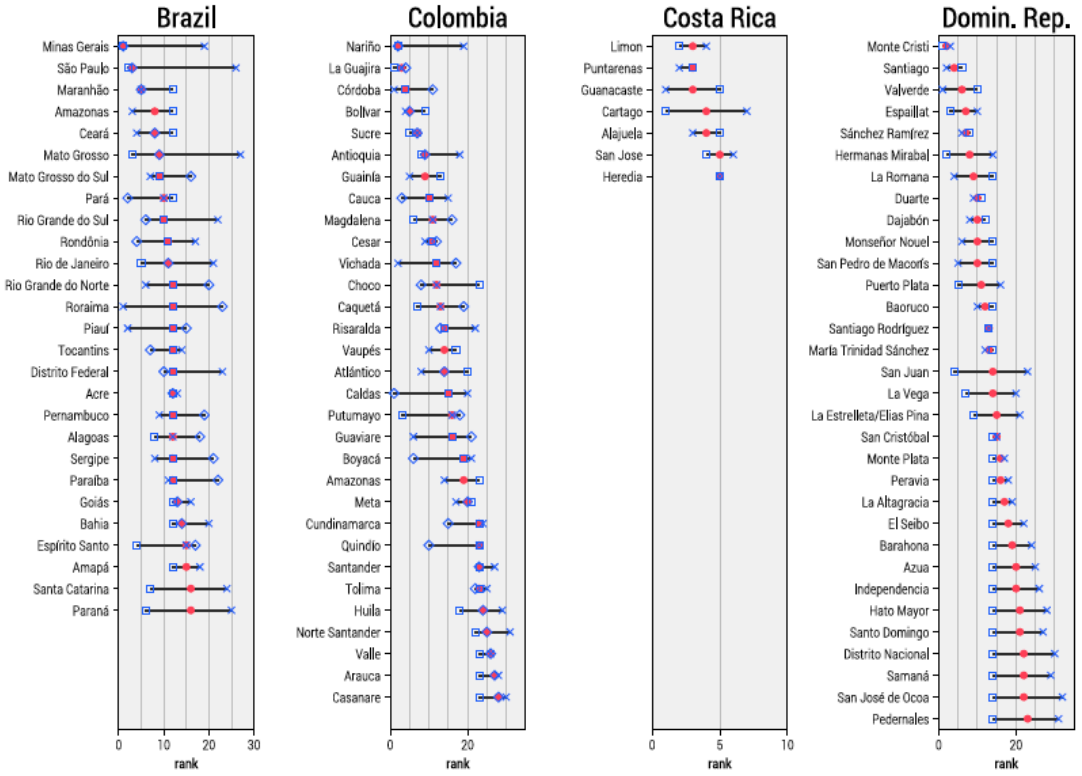




Perkins et al. Nat Microbiology 2016, Zhang et al. PNAS 2017

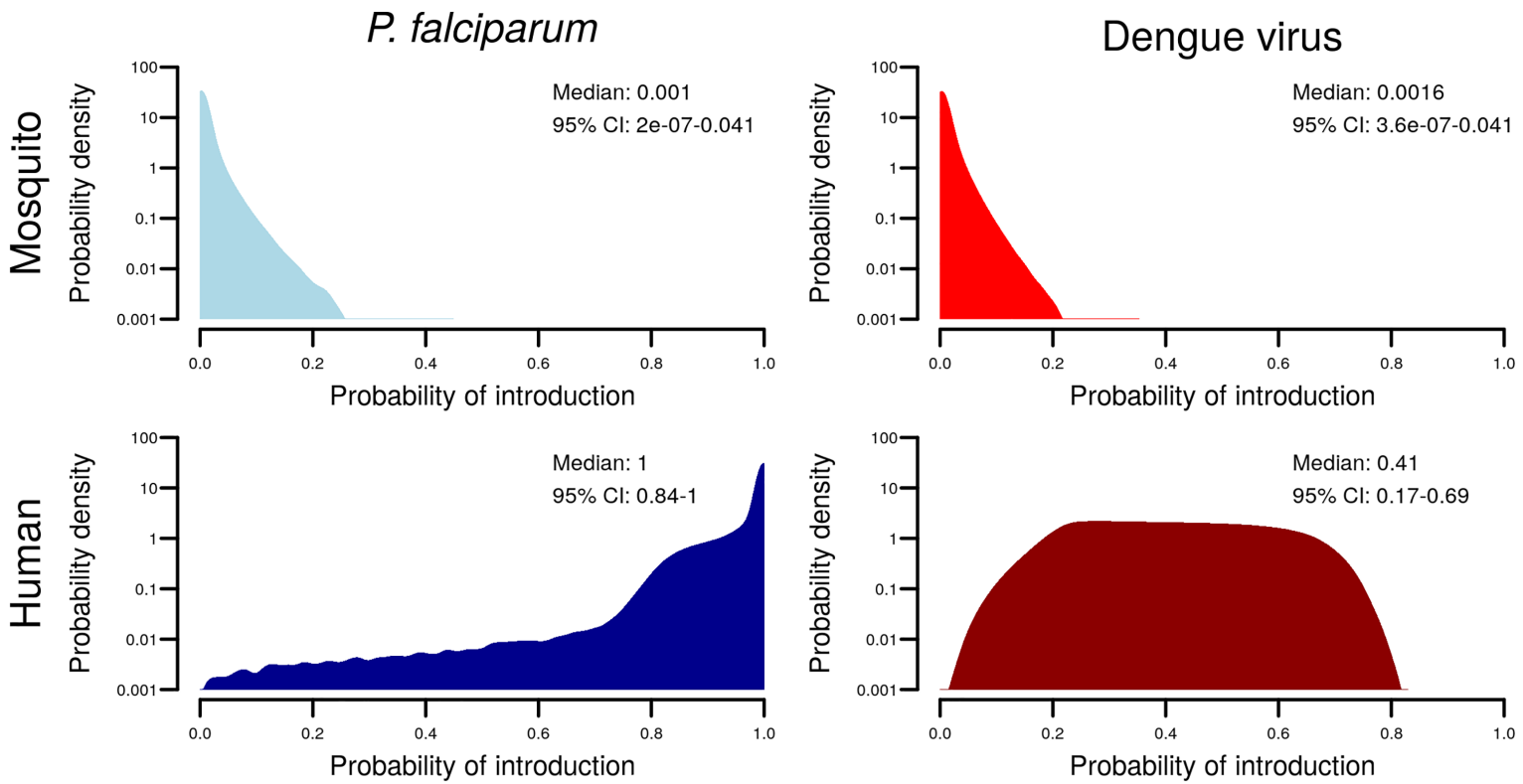
Vaccine development





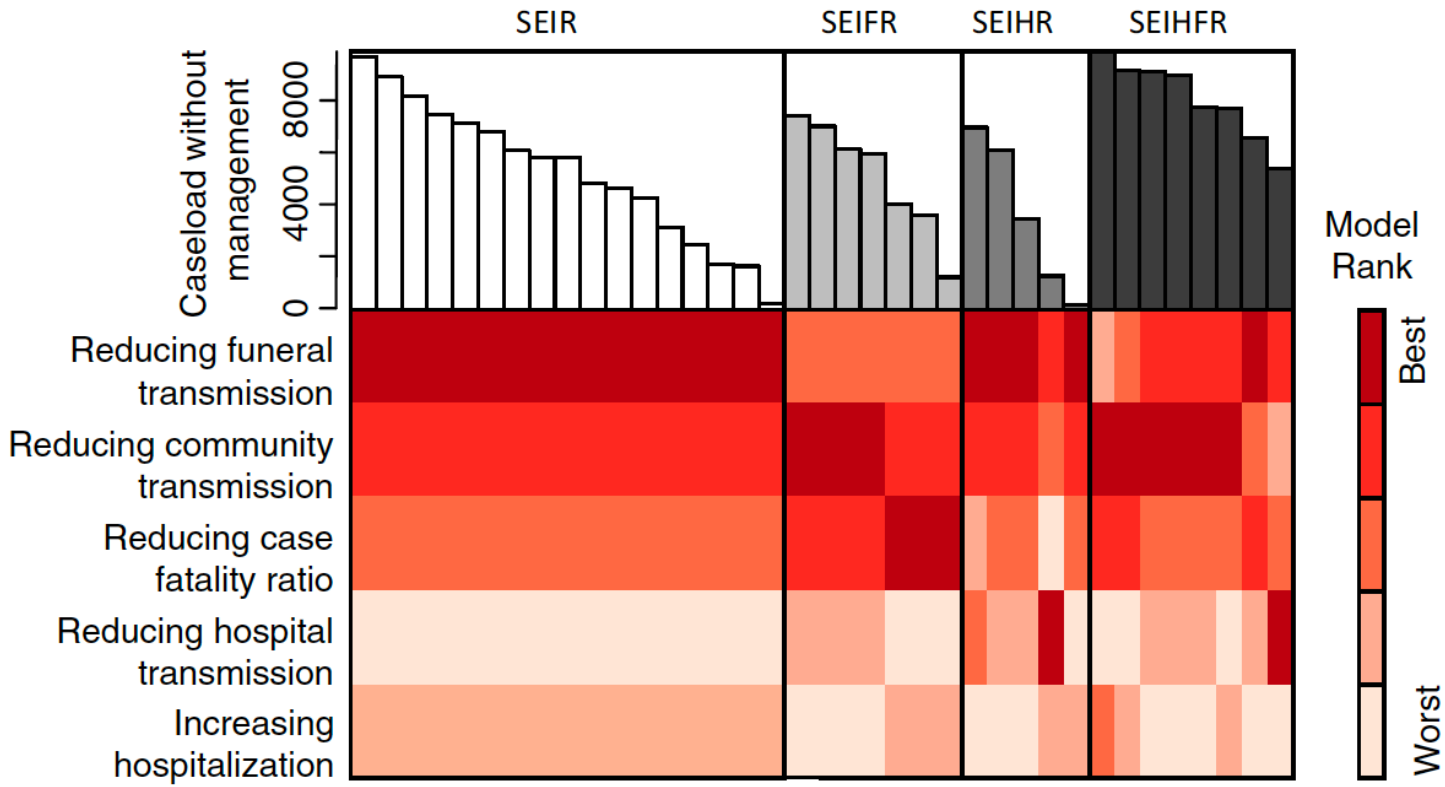
ZIKAVAT et al. Biorxiv 2017

Intervention planning (I)



Mier-y-Teran-Romero et al. PLOS NTD 2017

Intervention planning (II)



Li et al. PNAS 2017

Forecast assessment

- Timing and direction of spread are often predictable with some certainty for many locations.
- Models for estimating epidemic size and severity are improving.
- Models are being used to inform the development and selection of interventions and can be helpful even when the forecast itself is not.

Importance to vaccination

- What is the likely impact of vaccination (*a priori*)?
- Should a vaccine be prioritized?
- Is there time to develop a vaccine?
- Where and how should vaccine trials be planned?
- What strategy should be used for vaccination?
- What was the impact of vaccination on the epidemic (*a posteriori*)?

Final thoughts

Forecast of the future?

Disease	Current Activity	3-Month Outlook	Agency Action	Public Action
Dengue	Moderate	Ongoing transmission, epidemic unlikely	Maintain normal surveillance and prevention activities	Use caution and avoid contact with mosquitoes
Influenza	Moderate	Incidence increasing, peak likely in 2 months	Increase vaccine distribution and messaging	Get vaccinated
Pathogen X	High in country A	Possible local introduction	Educate travelers, prepare healthcare facilities, develop vaccine	Take precautions to avoid exposure and transmission if traveling

For more information, contact CDC
1-800-CDC-INFO (232-4636)
TTY: 1-888-232-6348 www.cdc.gov

The findings and conclusions in this report are those of the authors and do not necessarily represent the official position of the Centers for Disease Control and Prevention.