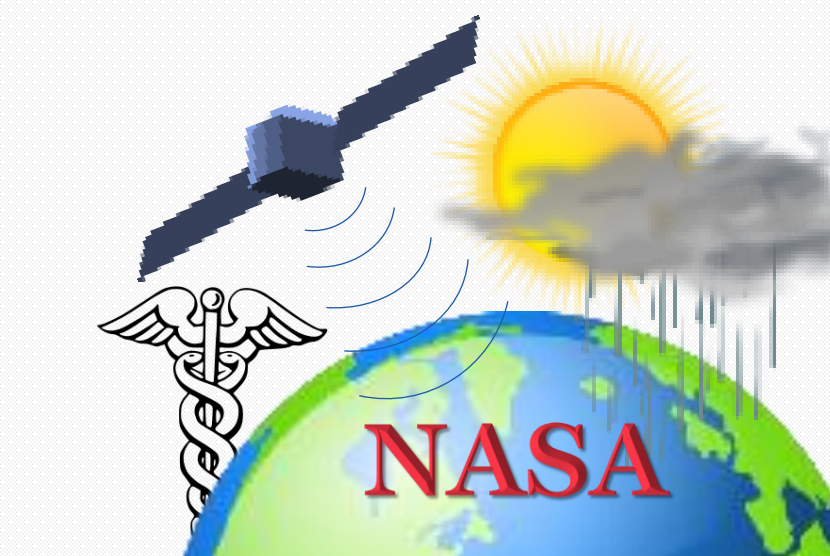


Modeled Forecasts of Dengue Fever in San Juan, PR Using NASA Satellite Enhanced Weather Forecasts

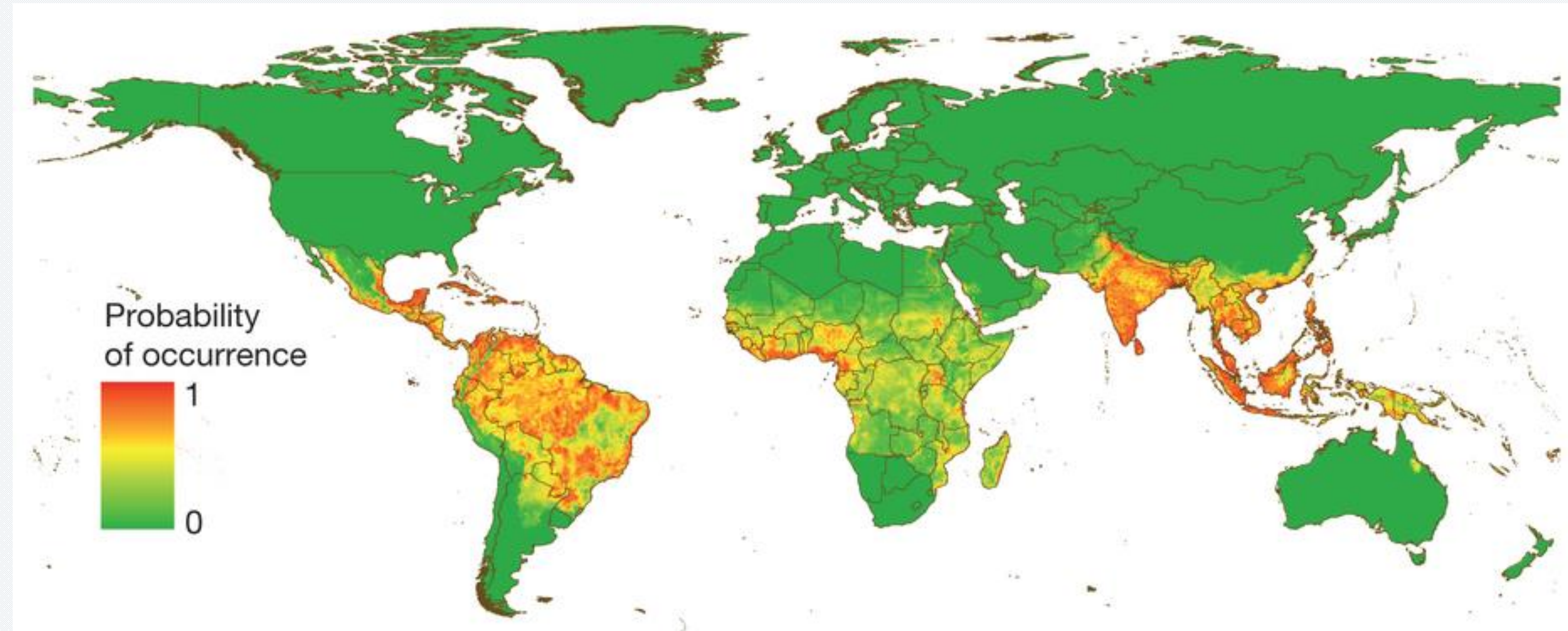


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1 - Background

Dengue virus is transmitted between humans and mosquitoes of the genus *Aedes* and causes approximately 96 million cases of disease (dengue fever) each year (Bhat et al. 2013). Symptoms of dengue fever include fever, headache, nausea, vomiting, and eye, muscle and joint pain (CDC). More severe manifestations such as abdominal pain, bleeding from nose and gums, vomiting of blood, and clammy skin occur in rare cases of dengue hemorrhagic fever (CDC). Dengue fever occurs throughout tropical and sub-tropical regions worldwide, however, the geographical range and size of epidemics is increasing. Weather and climate are drivers of dengue virus transmission dynamics (Morin et al. 2013) by affecting mosquito proliferation and the virus extrinsic incubation period (i.e. required time for the virus to replicate and disseminate within the mosquito before it can retransmit the virus).



Probability of dengue fever occurrence (Bhatt et al. 2013)

2 - Project Overview

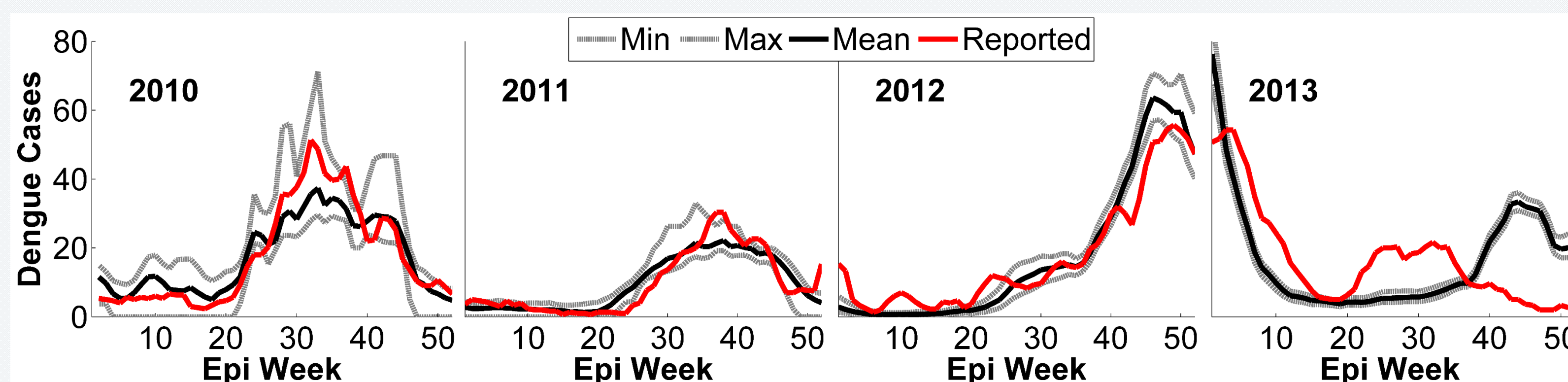
Meteorological conditions exert strong influences on dengue virus ecology:

Temperature-Vector: Mosquito development rates
Mosquito mortality rates
Mosquito reproductive behavior

Temperature-Virus: Virus extrinsic incubation period

Precipitation-Vector: Mosquito habitat creation and maintenance

Using quantitative measures of these relationships, it is possible to simulate dengue virus transmission using meteorological and demographic data. The Dynamic Mosquito Simulation Model (DyMSiM) uses these principles to simulate dengue fever case numbers in San Juan, PR (Morin et al. 2015). This project will use a methodology to make one week forecasts of dengue fever cases using dynamically downscaled weather forecasts to drive DyMSiM and reported dengue fever case numbers for model parameterization.



Minimum, maximum, and mean simulated vs reported cases of dengue fever using the DyMSiM model in San Juan, PR (Modified from Morin et al. 2015)

3 - Methods

A - Data

Meteorological station data

Daily maximum temperature

Daily minimum temperature

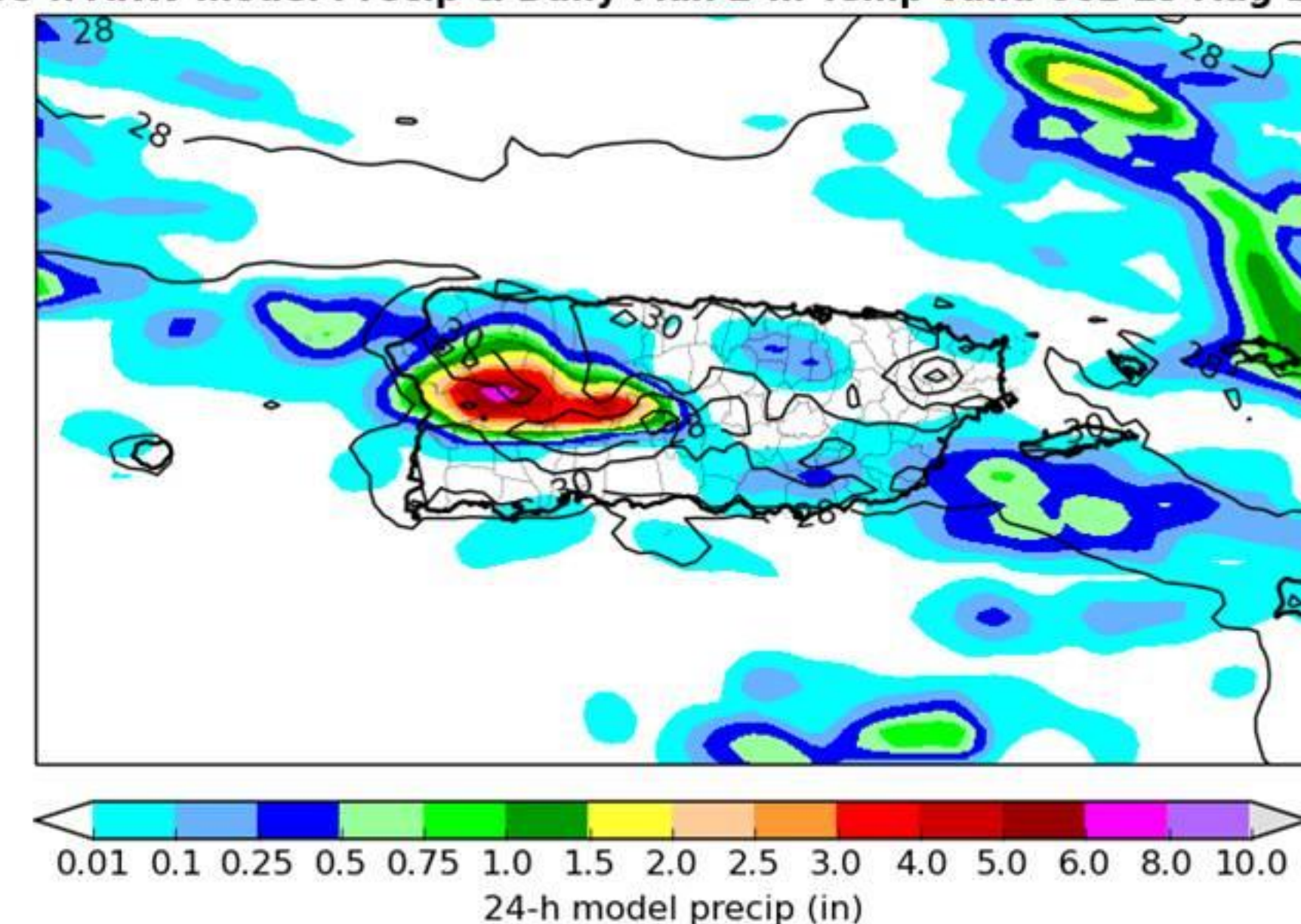
Daily total precipitation

Puerto Rico Department of Health

Weekly reported dengue cases

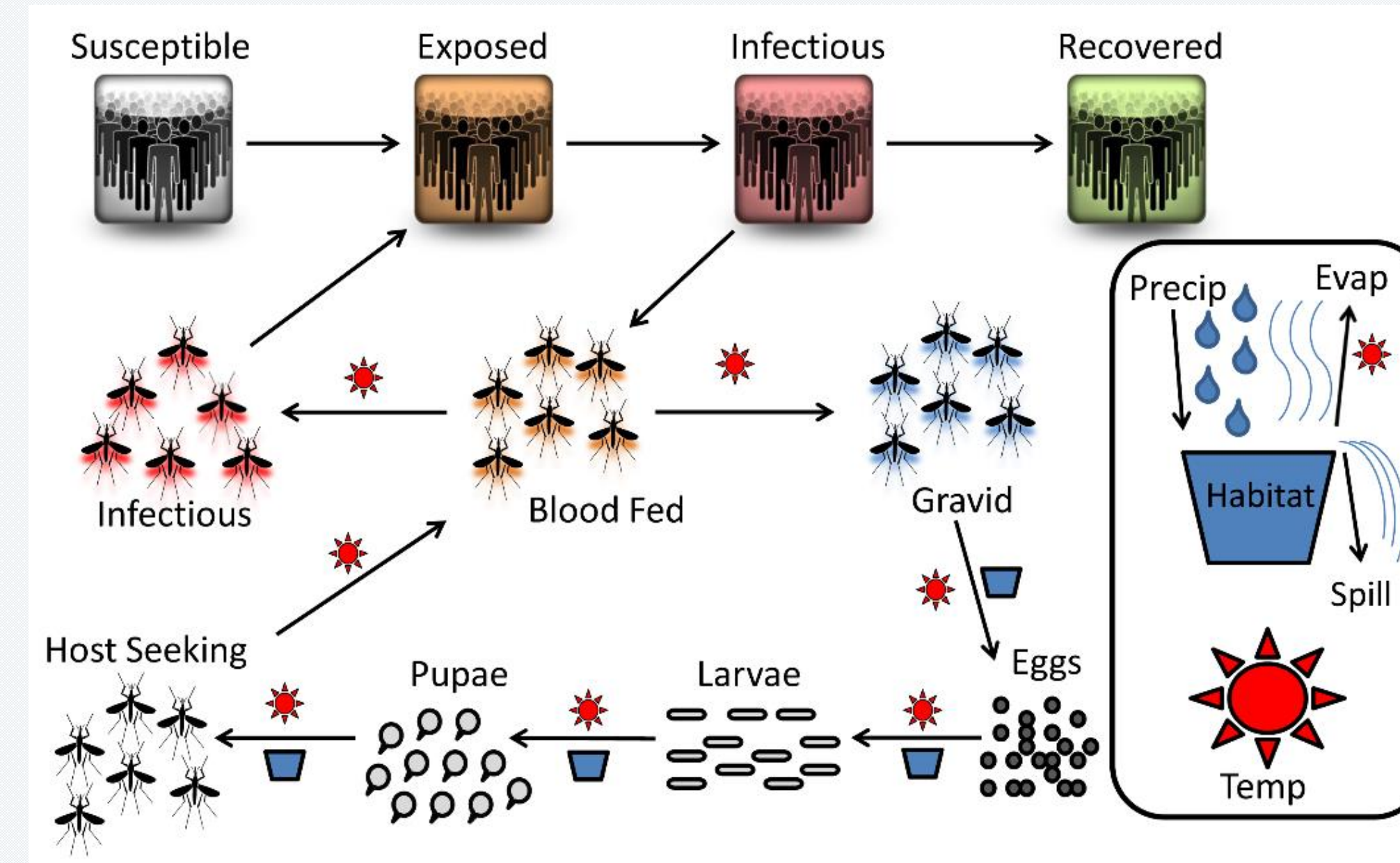
B - Weather Forecasts

168-h ARW model Precip & Daily Max 2-m Temp valid 00z 19 Aug 2015



Meteorological forecasts were generated using NWP forecast data generated by initializing the WRF model using NASA MODIS and VIIRS datasets and initial and boundary conditions from the operational NCEP Global Forecast System model. Each week, a WRF simulation was run at 4-km horizontal grid spacing (left) to generate 10 days of downscaled daily maximum and minimum temperature and accumulated precipitation.

C - DyMSiM



DyMSiM is a process driven model that calculates virus transmission by simulating the mosquito life cycle and the progression of virus infections in both mosquitoes and humans (left). Mosquito population dynamics are simulated using temperature based rates of mosquito development, mortality, and reproductive behavior and water habitat (required for eggs, larvae, and pupae) formation and maintenance, calculated as a

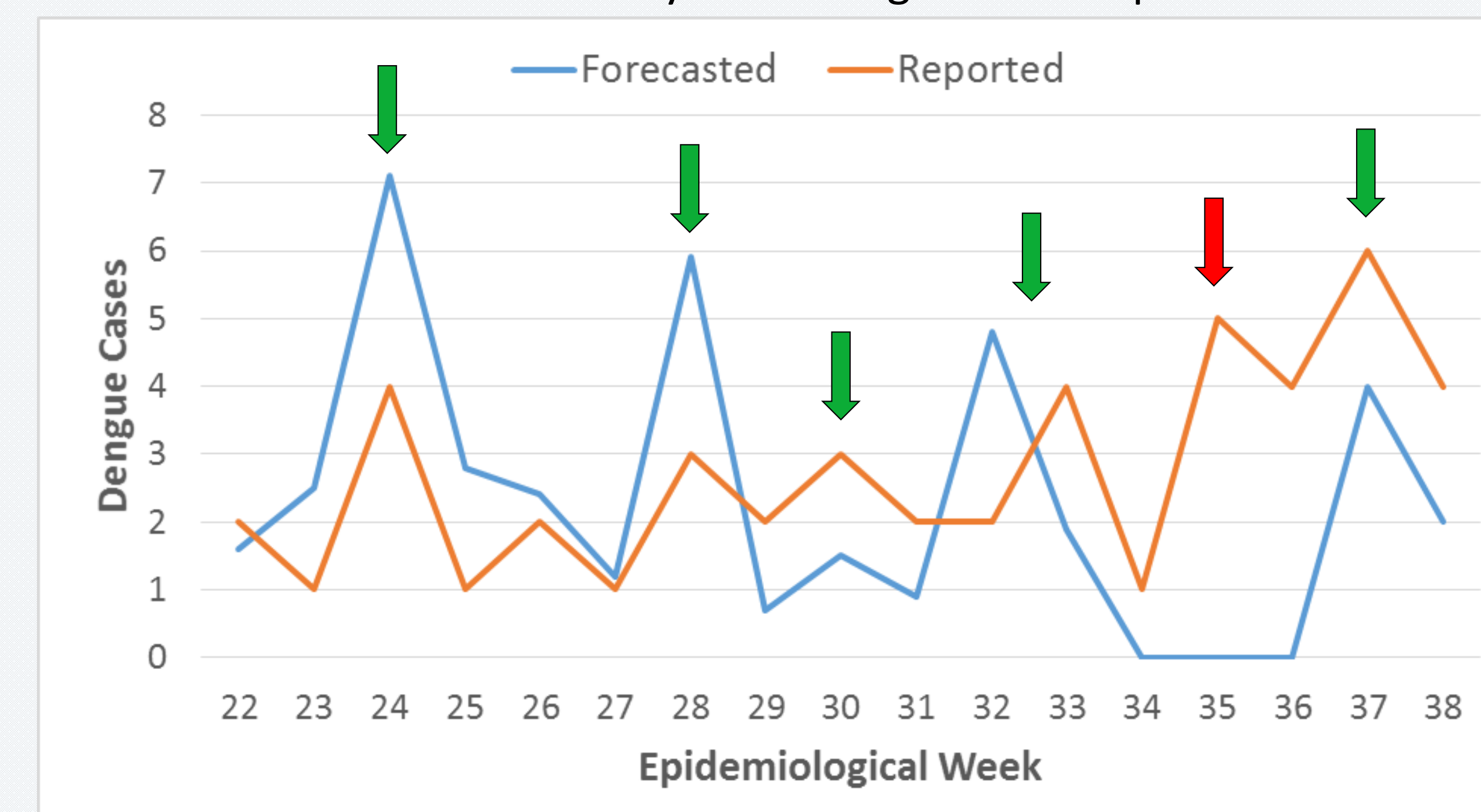
balance between precipitation and evaporation. The virus is transmitted between the human and mosquito population during the female mosquito's blood meals. Infected humans and mosquitoes experience an incubation period during which the virus replicates in their system until the density of virus is high enough to cause new infections during feeding.

D - Dengue Forecasting Process

- 1: Perform simulations using weather station data and various model parameterizations
- 2: Evaluate the simulations by comparing the results with the reported dengue case data
- 3: Select simulation parameterizations that best replicate the reported dengue case data
- 4: Rerun the selected simulations one week into the future using the weather forecast data
- 5: Use simulation results to produce a one week forecast of dengue fever case numbers
- 6: Repeat steps 1-5 each week
- 7: Evaluate forecasts

4 - Results and Discussion

The forecasting method was successful at predicting spikes in dengue fever cases (below) within one week of their reported occurrence (green arrows) with one exception during week 35 (red arrow). However, with such low case numbers, it is difficult to determine the skill of the model. The strong ENSO event that coincided with the period of this study resulted in severe drought conditions in San Juan, PR. Consequently, dengue virus transmission was likely limited due to a dearth of mosquito aquatic habitat. Still, the forecasting technique was able to simulate subtle signals and the influence of drought on dengue virus transmission. The missed spike in dengue cases during weeks 35 and 36 were probably due to the algorithm used to generate the forecasts which had difficulty recovering from case predictions near zero.



Forecasted vs reported cases of dengue fever

5 - Conclusions and Future Work

The dengue forecast system was successfully implemented for San Juan, PR but the accuracy of the system is still unclear. The algorithm for transforming model simulations into dengue case forecasts needs to be reexamined so that it can better recover from near zero predictions. This work will be expanded in 2016. Weather and dengue fever case forecasts will once again be produced for San Juan and also other municipalities in Puerto Rico and other nearby Caribbean countries such as Haiti, the Dominican Republic, Jamaica, and the US Virgin Islands. Additionally, DyMSiM will be modified so that forecasts can be produced for another important *Aedes* mosquito transmitted pathogen, Chikungunya virus. Lastly, the forecast system will be introduced to and evaluated by researchers at the Centers for Disease Control and Prevention. Feedback from end-users will be essential for creating an automated disease forecast system that is timely, effective, and intuitive to use.



Ae. aegypti from www.vectorbase.org

6 - Works Cited

Bhatt S, Gething PW, Brady OJ, Messina JP et al. The global distribution and burden of dengue. *Nature* 2013;496:504-507.
Centers for Disease Control and Prevention. Dengue. Accessed 11 November 2015. Available at: <http://www.cdc.gov/Dengue/>.
Morin CW, Comrie AC, Ernst K. Climate and dengue transmission: evidence and implications. *Environ Health Perspect* 2013;121:1264-1272.
Morin CW, Monaghan AJ, Hayden MH, Barrera R et al. Meteorologically driven simulations of dengue epidemics in San Juan, PR. *PLoS Negl Trop Dis* 2015;9:e0004002.