Spatially explicit transmission dynamic models for malaria elimination in the Greater Mekong Sub-Region

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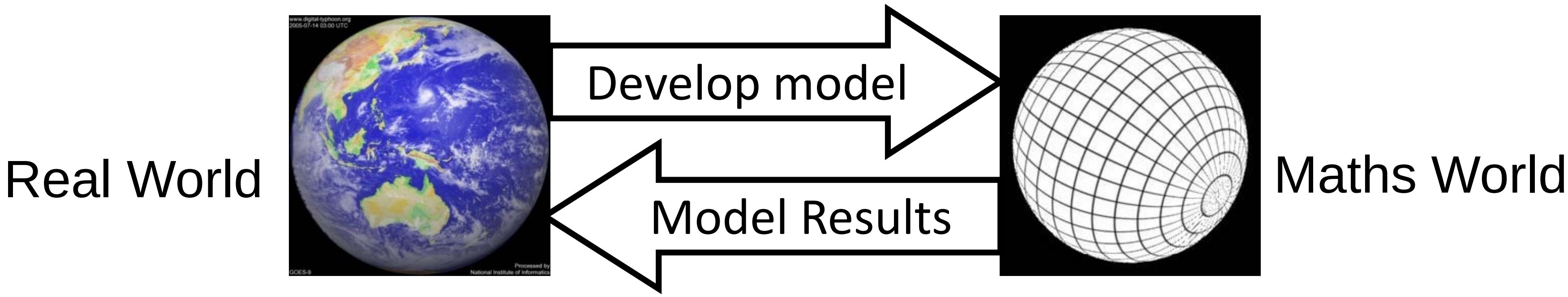
What is a model?

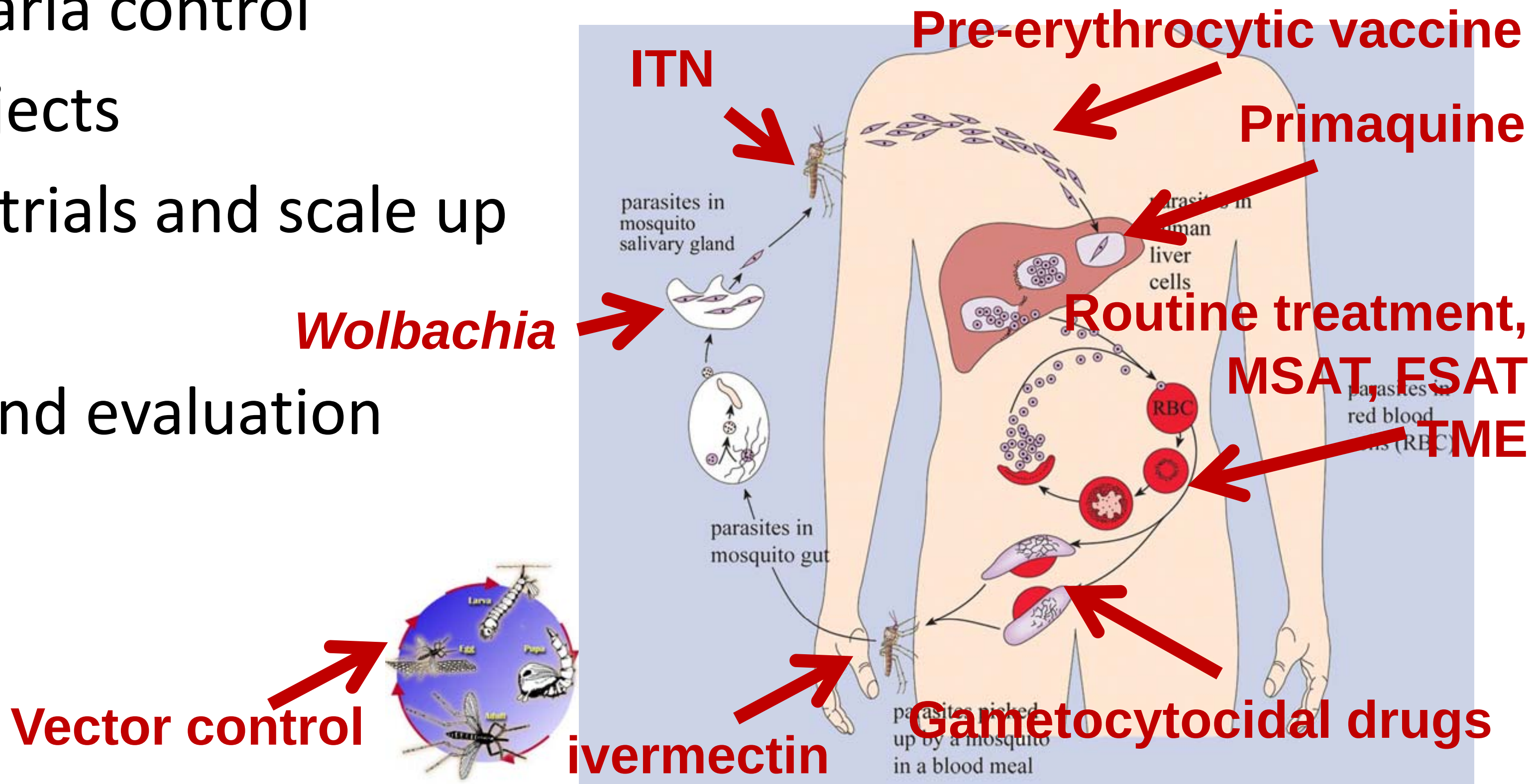
- A simplified description of a system or process used to aid understanding



- **Mathematical models** are especially useful for complex dynamic systems like infectious disease transmission

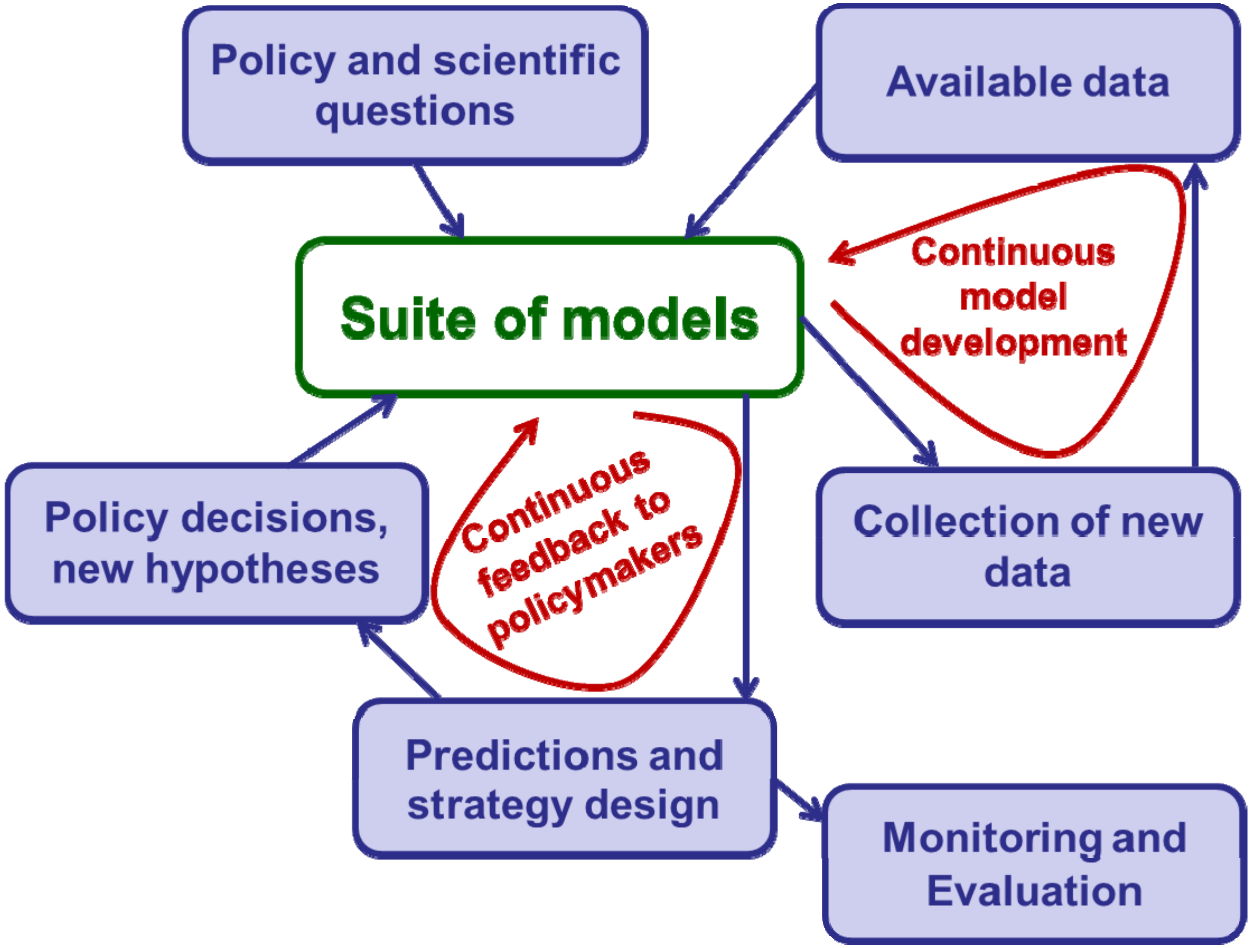
Why do mathematical modelling?

- Multiple sub-optimal intervention options
- Multiple sources of data
  - national malaria control
  - research projects
  - intervention trials and scale up
  - surveillance
  - monitoring and evaluation



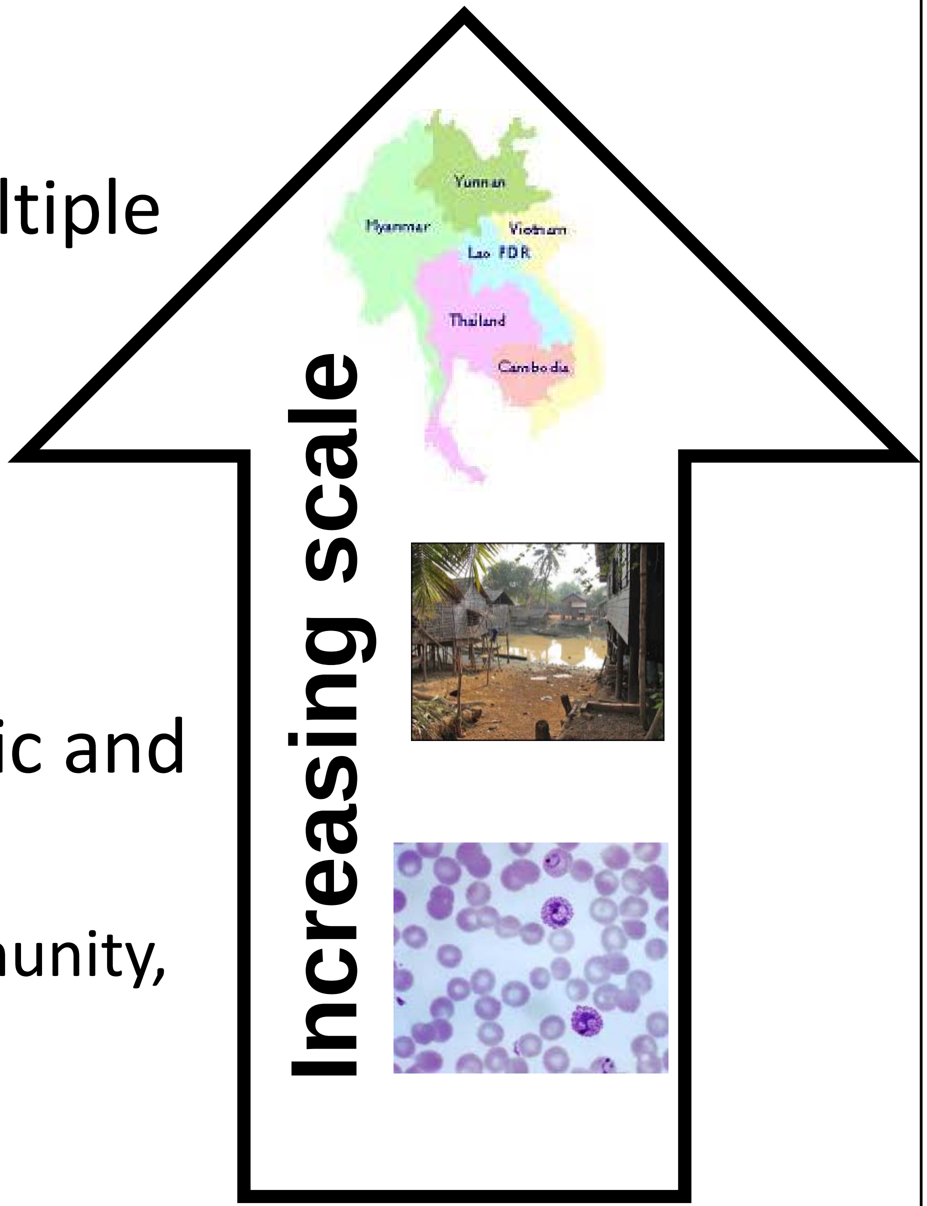
Using models for data-driven decision support

- The models would be fully integrated into
  - Health economics
  - The malaria control programs and other stakeholders and policymakers
  - cutting edge medical and biological research in the GMR
- Expect a significant reduction in the time between research results and program implementation



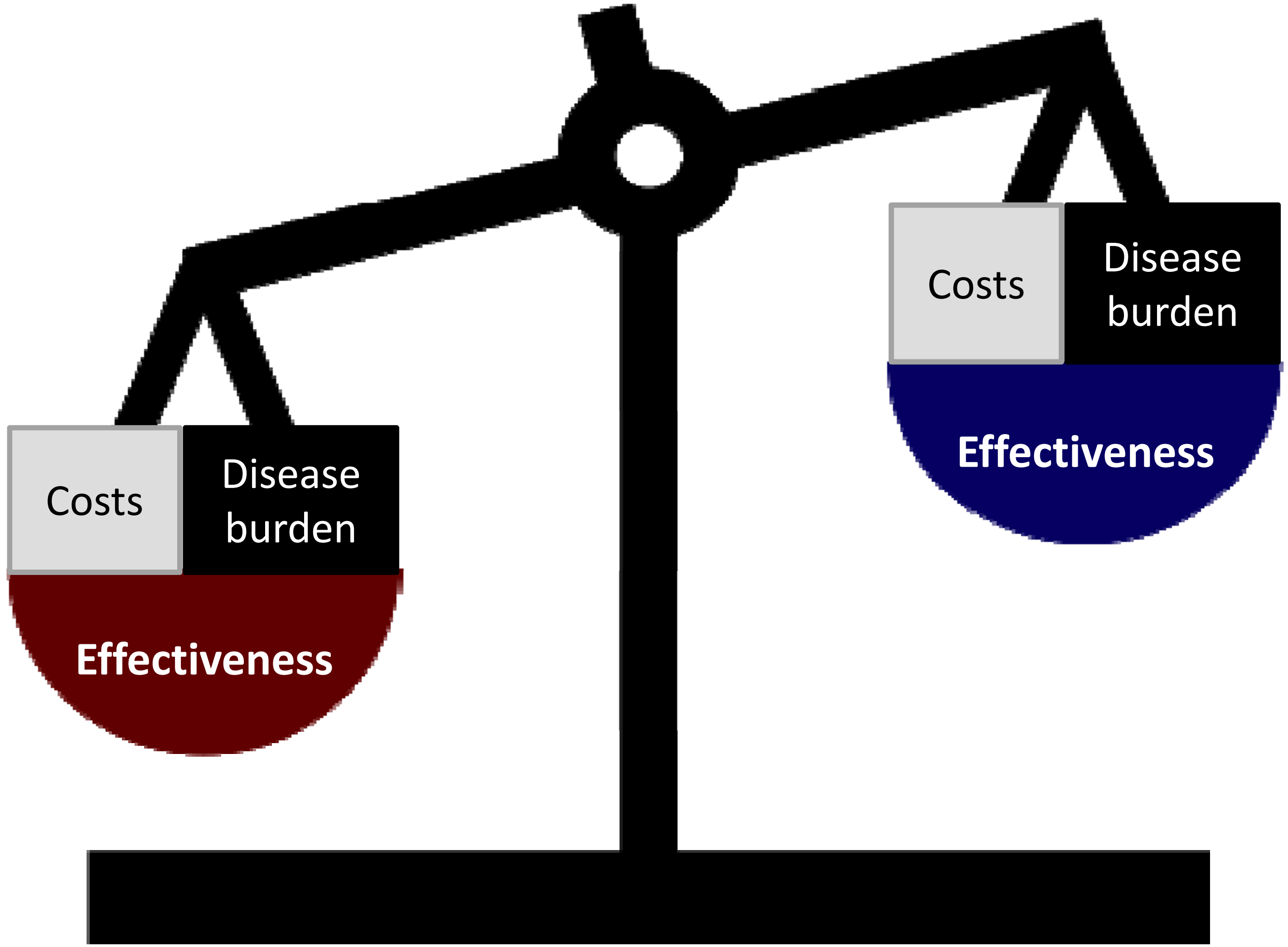
Modeling Approaches

- Spatially explicit economic-epidemiological model with multiple resolution options
  - Elimination strategy design
- Individual-based models
  - Trial design and simulation
- Within-host models (mechanistic and statistical)
  - Treatment, infectious period, immunity, drug resistance



Economic Evaluation

An **economic evaluation** compares the incremental costs and consequences of two alternative options.

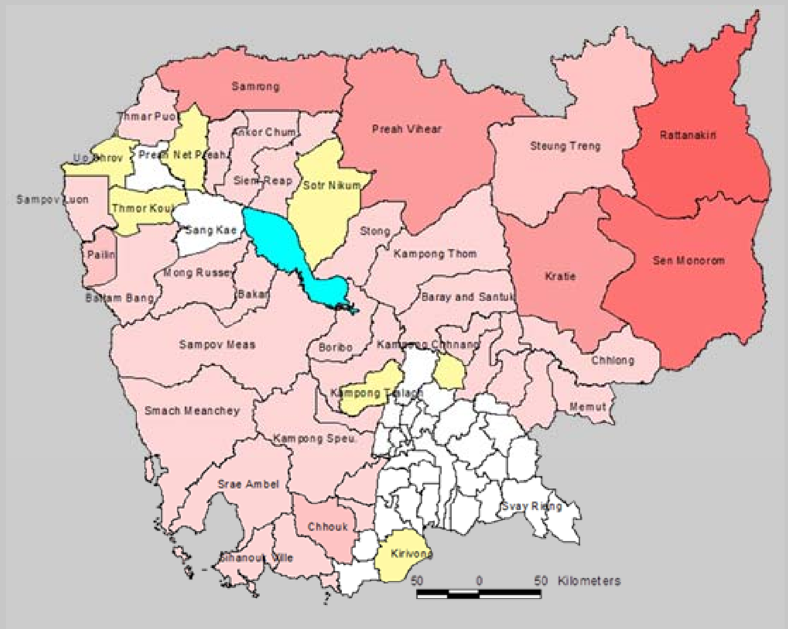


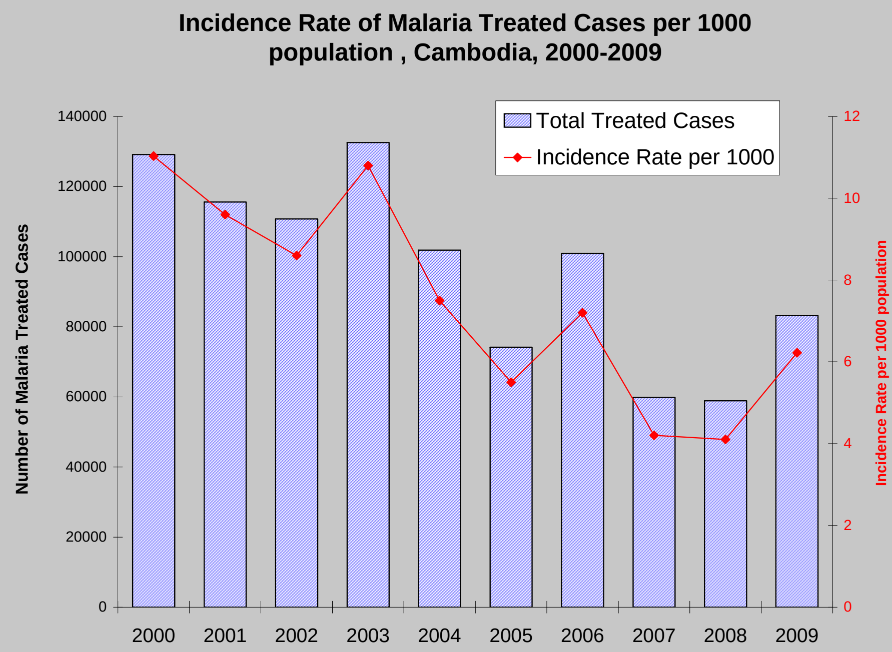
A model for Cambodia

Transmission and control mechanistic model [FLOWS]

Population behaviour and movement model

Space → **Stochastic Patch Model** ← **Time**





population density data (census)

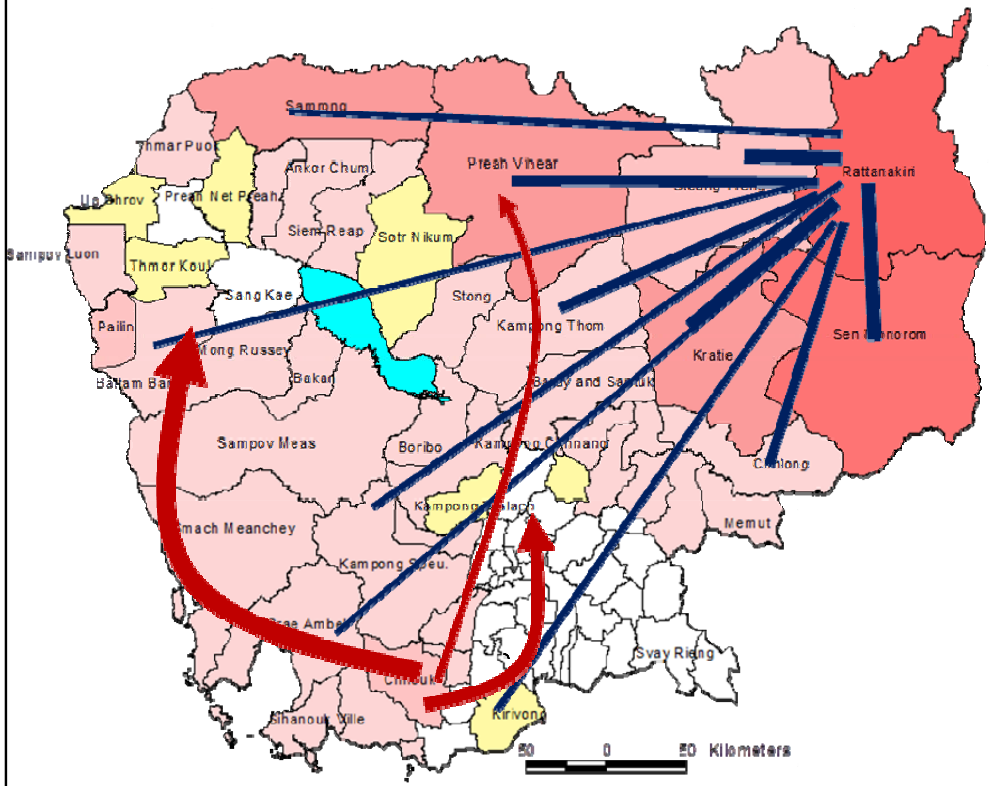
Incidence data (HIS, VMW)

Intervention coverage data (ITN, VMW)

Population behaviour and movement data

Environmental data (landcover, ONI)

Population behavior and movement model

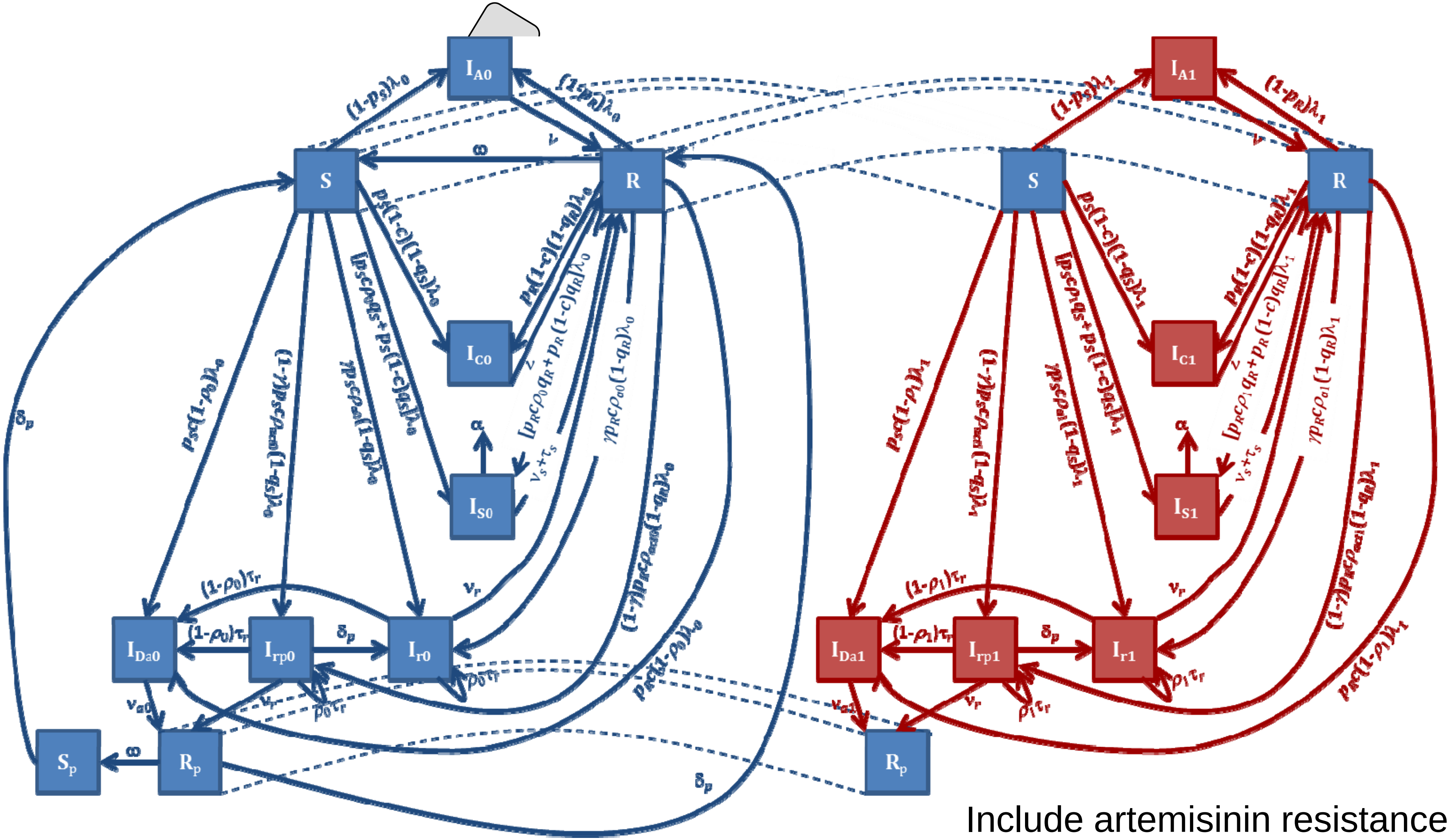


- 3 subpopulations in each patch
  - Static
    - People who do not move home but have connectivity with people from other patches
  - Mobile
    - People who between patches
  - Remote
    - People who do not move home and have little connectivity with people from other patches

Connectivity between patches for static populations inversely proportional to distance

Movement of mobile populations to be defined by data from the national census and from specially designed studies

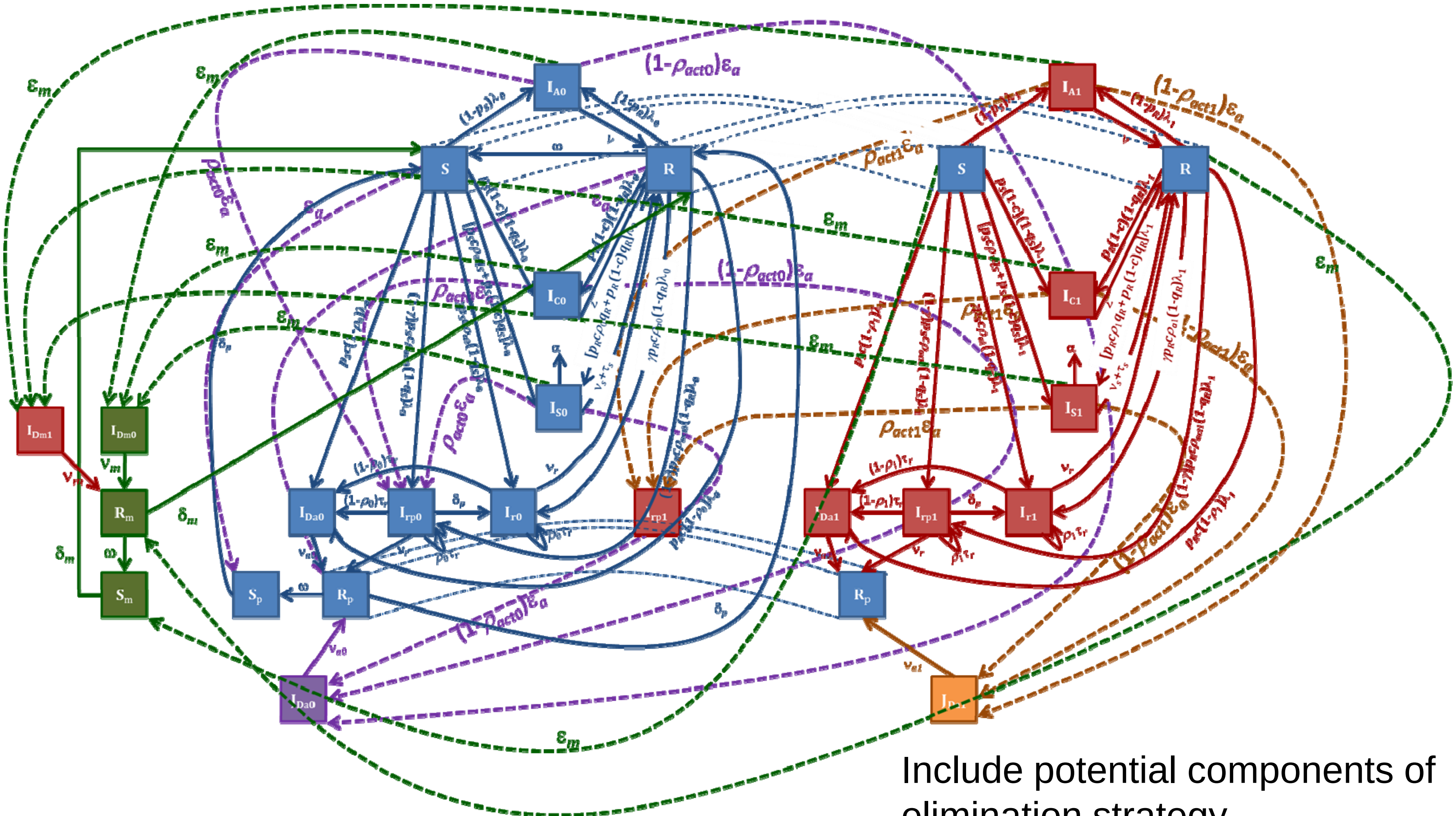
Transmission model



Include artemisinin resistance

Include treatment and recrudescence

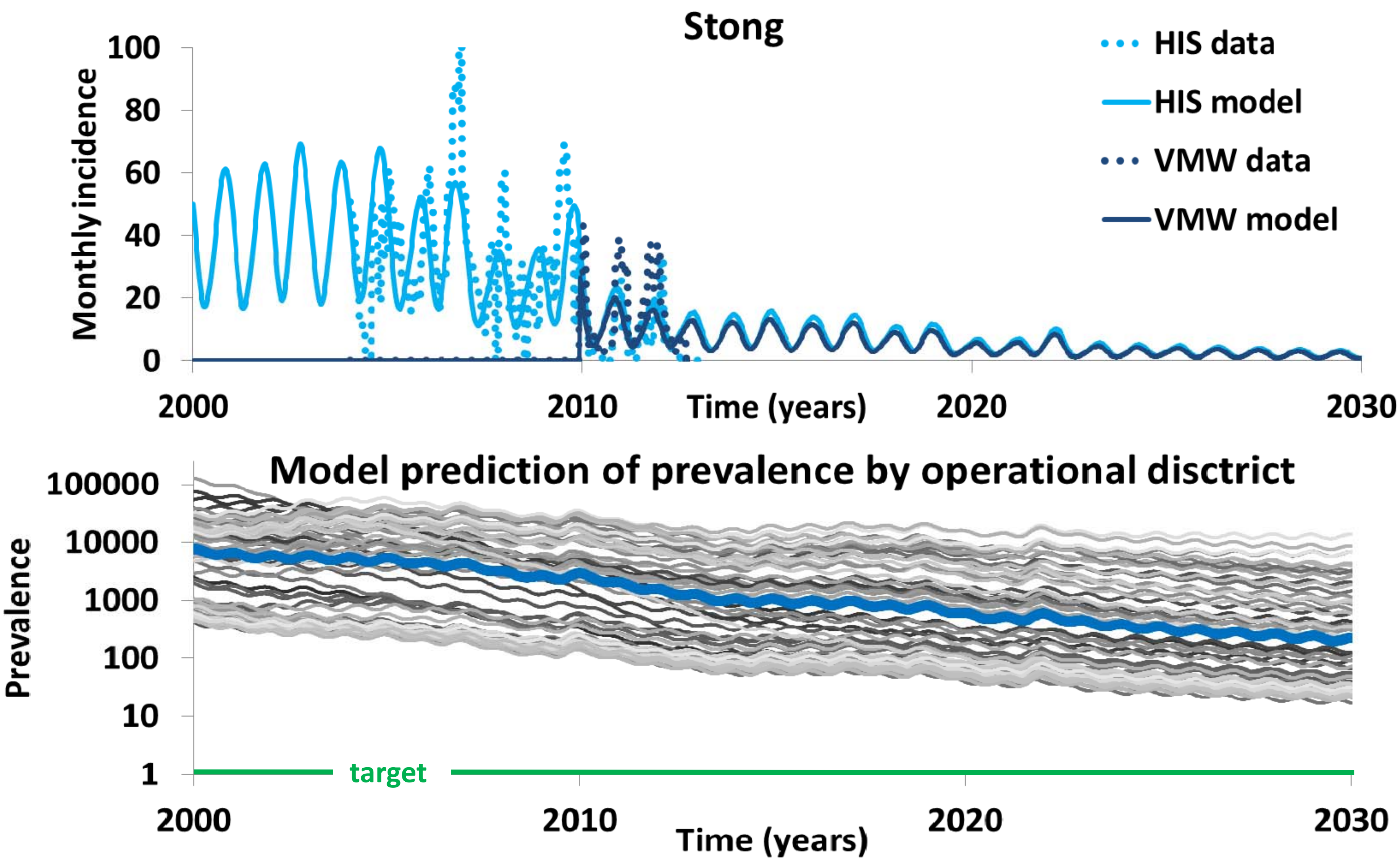
Transmission model



Include potential components of elimination strategy

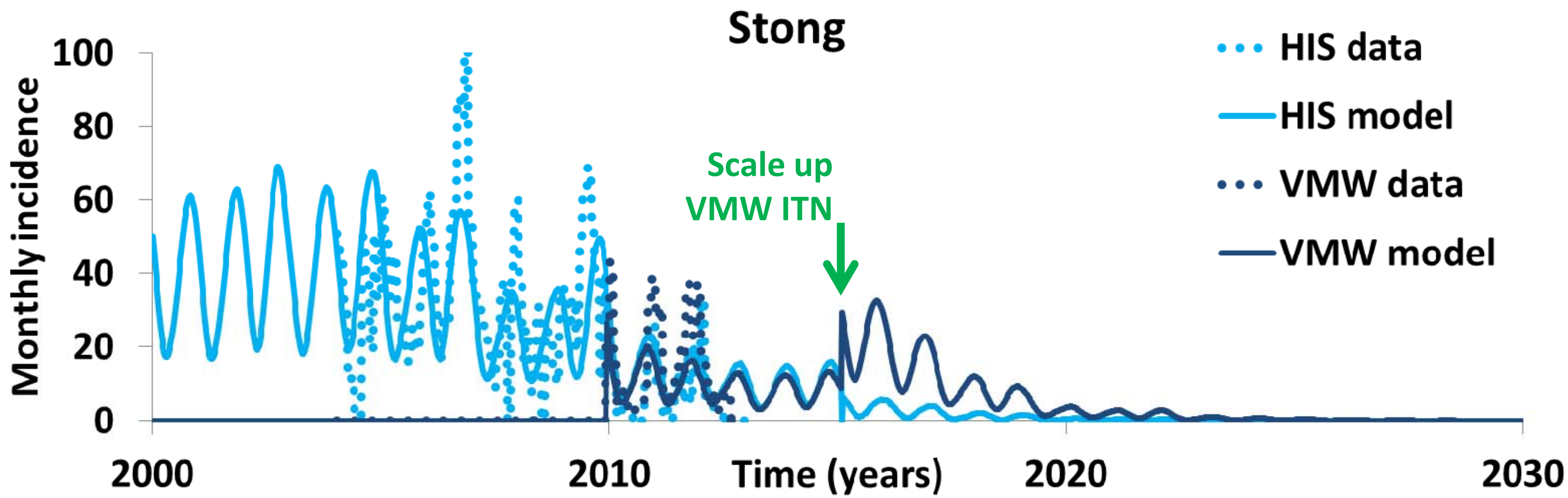
Preliminary results

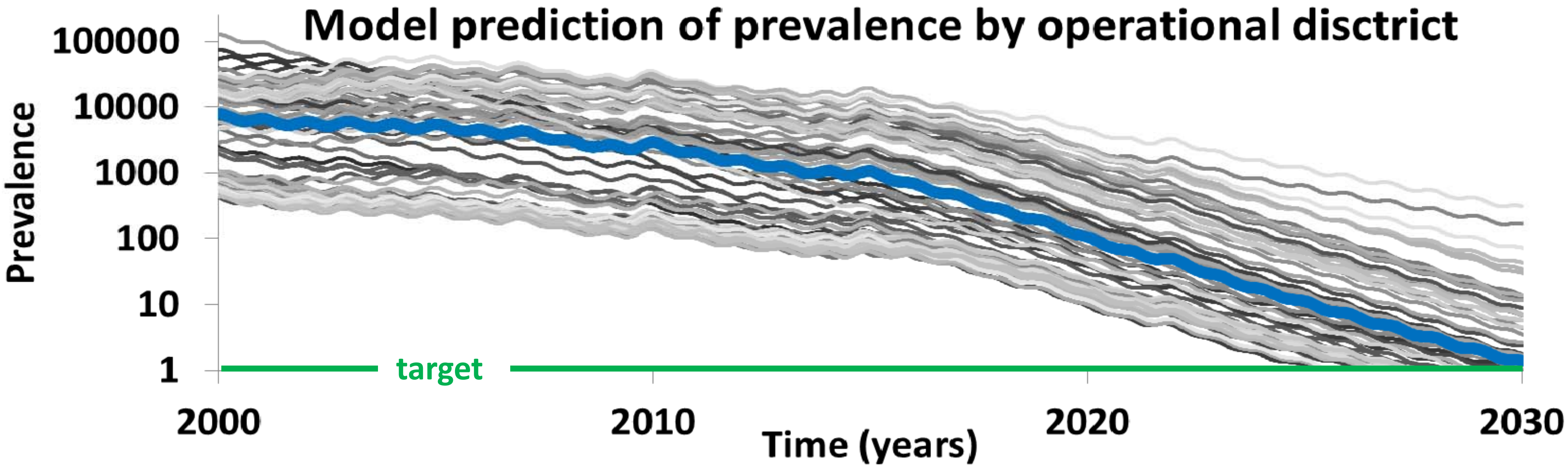
- Model estimates: **65%** of clinical cases will visit a VMW if present; Ownership of ITN reduces biting by **25%;** ITNs are effective for **18 months**



Elimination strategy design: scale up

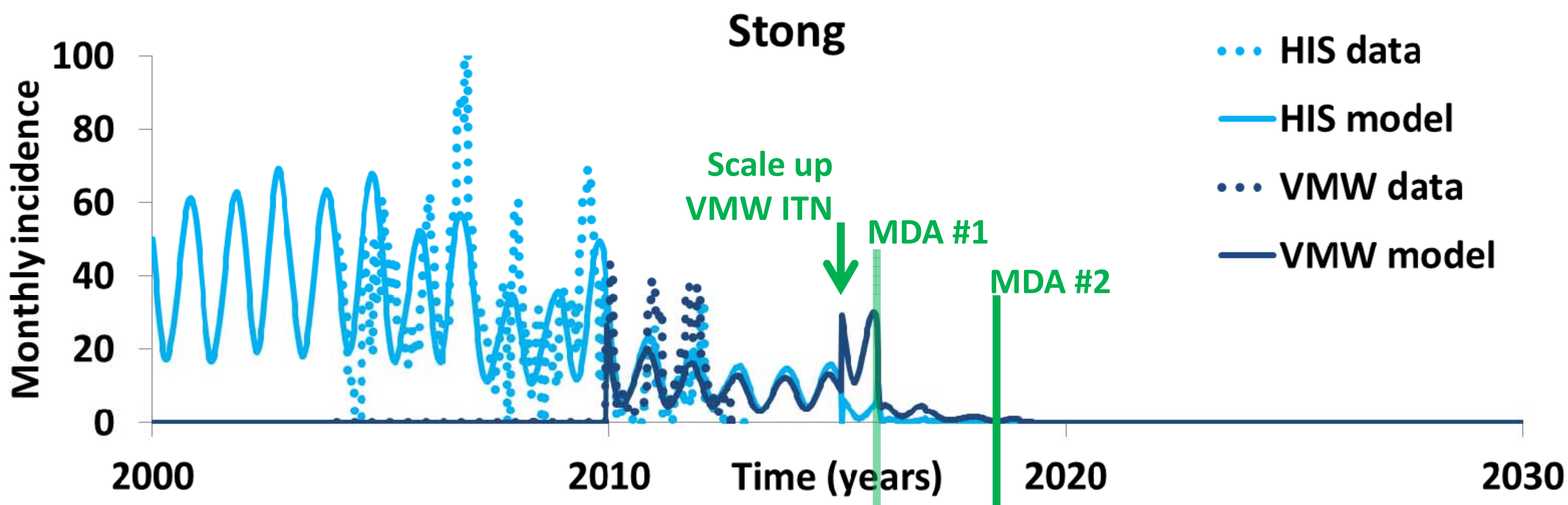
- In **45** ODs: Scale up VMW scheme to **80%** of all villages; Scale up ITN coverage to **80%** and renew every **18 months**
- No further interventions

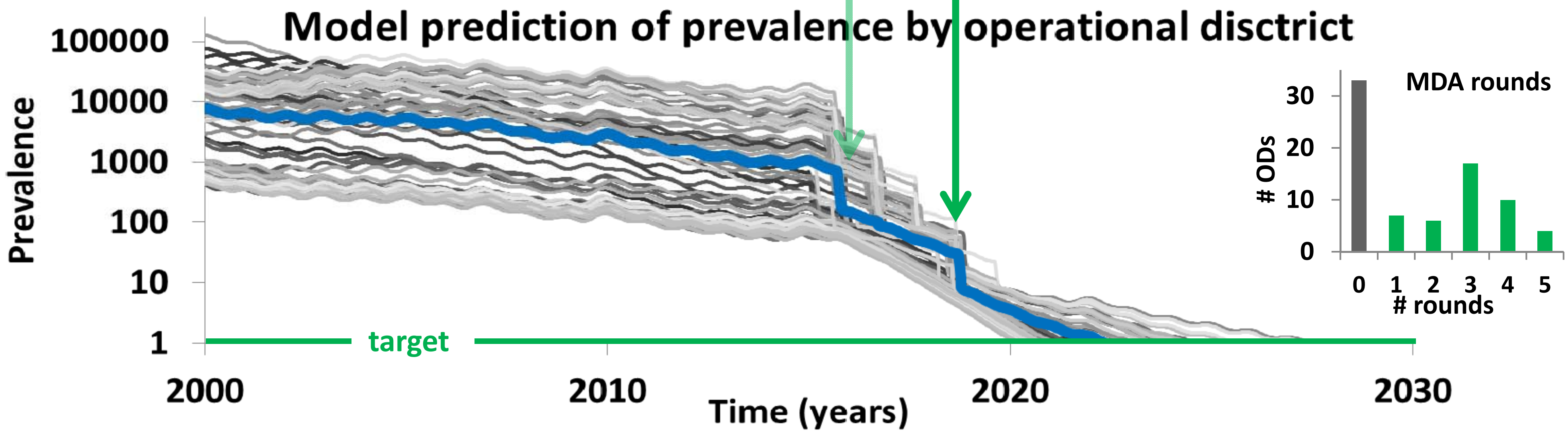




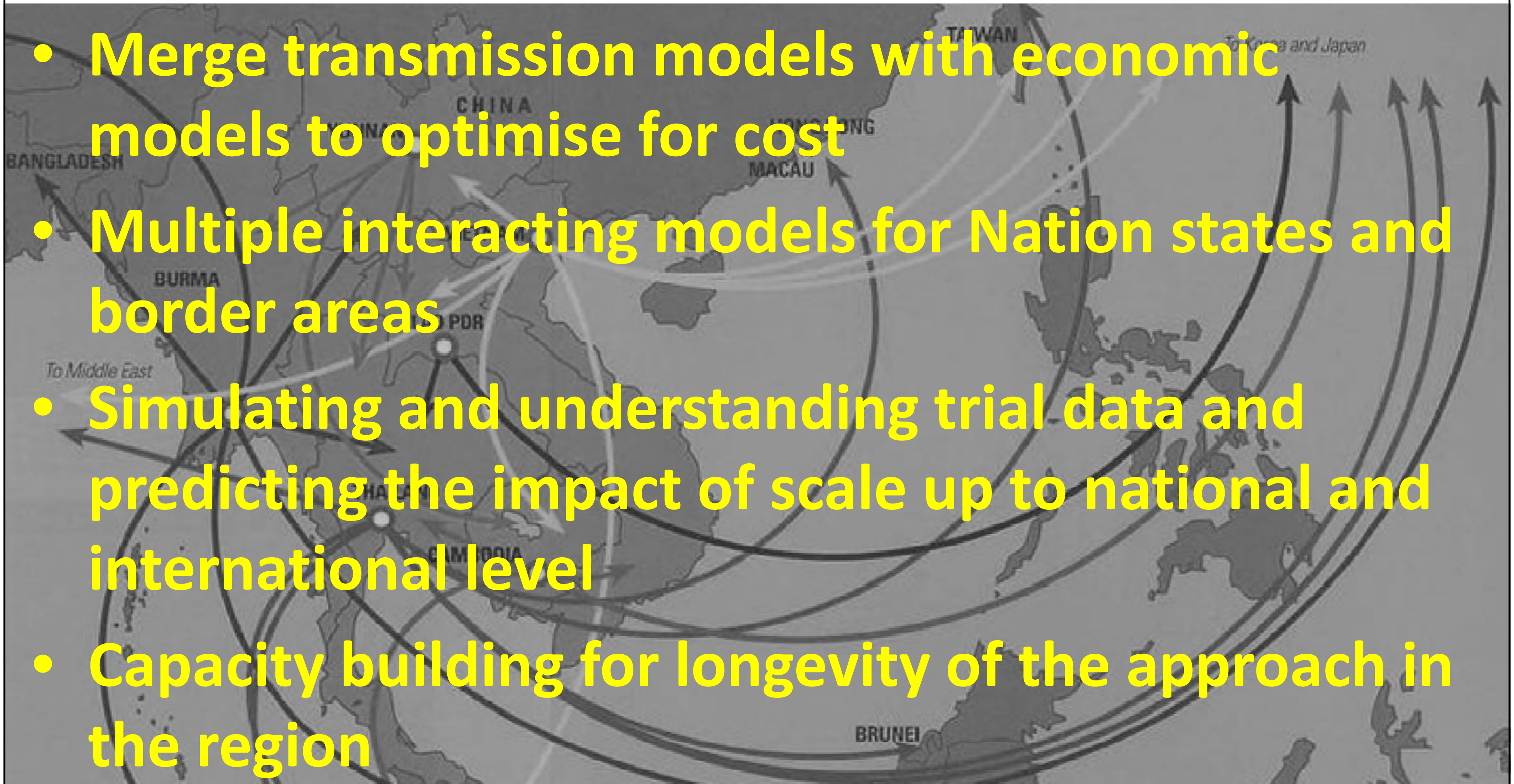
Elimination strategy design

- In **45** ODs: Scale up VMW scheme to **80%** of all villages; Scale up ITN coverage to **80%** and renew every **18 months**
- MDA in annual rounds: Coverage **80%;** Number of rounds tailored to OD





Potential contribution of economic-epidemiological models to malaria elimination in the Greater Mekong Subregion



- Merge transmission models with economic models to optimise for cost
- Multiple interacting models for Nation states and border areas
- Simulating and understanding trial data and predicting the impact of scale up to national and international level
- Capacity building for longevity of the approach in the region

http://www.mekongmigration.org/?page_id=25

Acknowledgements

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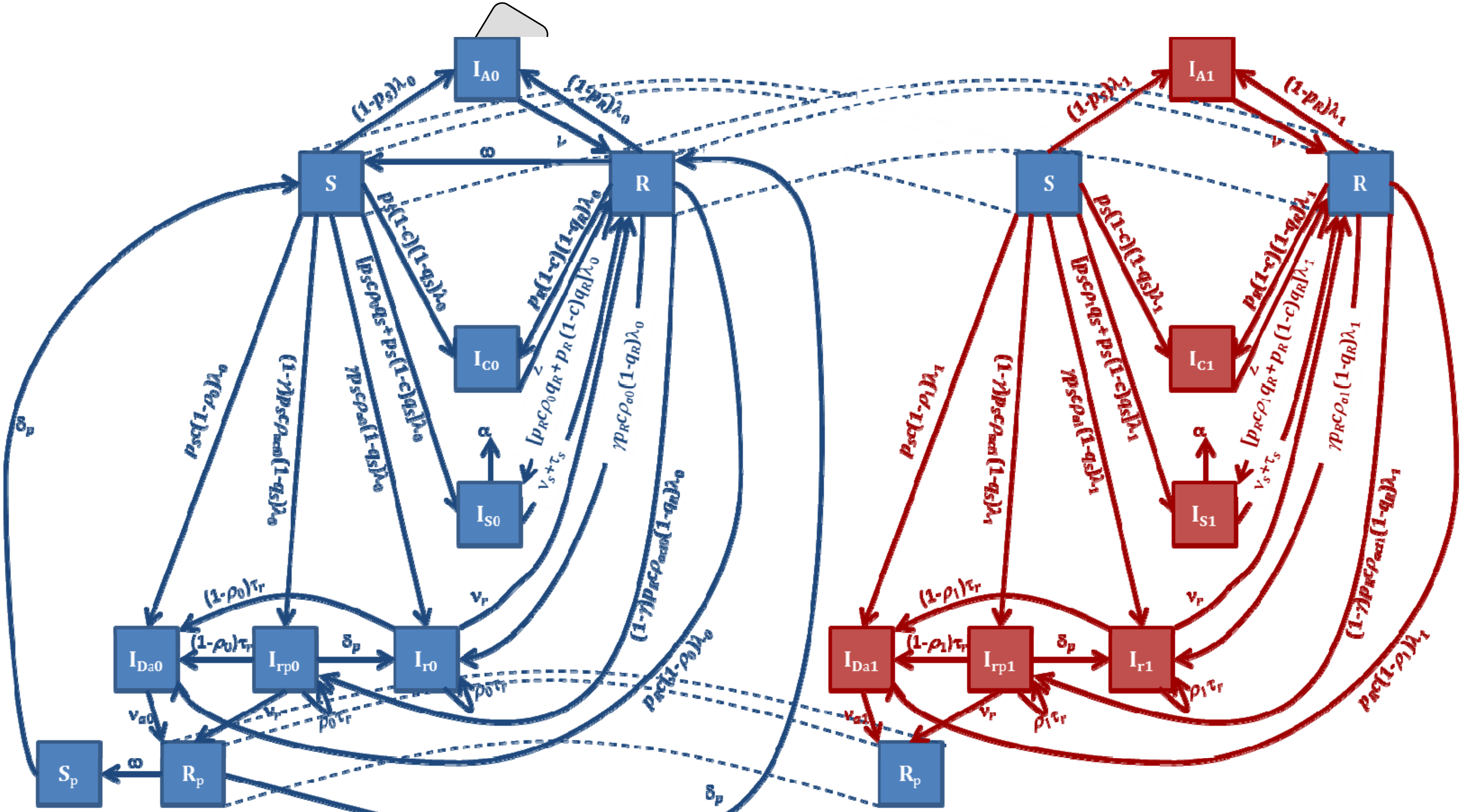
- Center of Malariology, Parasitology, and Entomology, Laos
- Institute of Malariology Parasitology and Entomology, Vietnam
- DMR, Myanmar
- UNOPS, Myanmar

Extra Slides

Transmission model



Include artemisinin resistance

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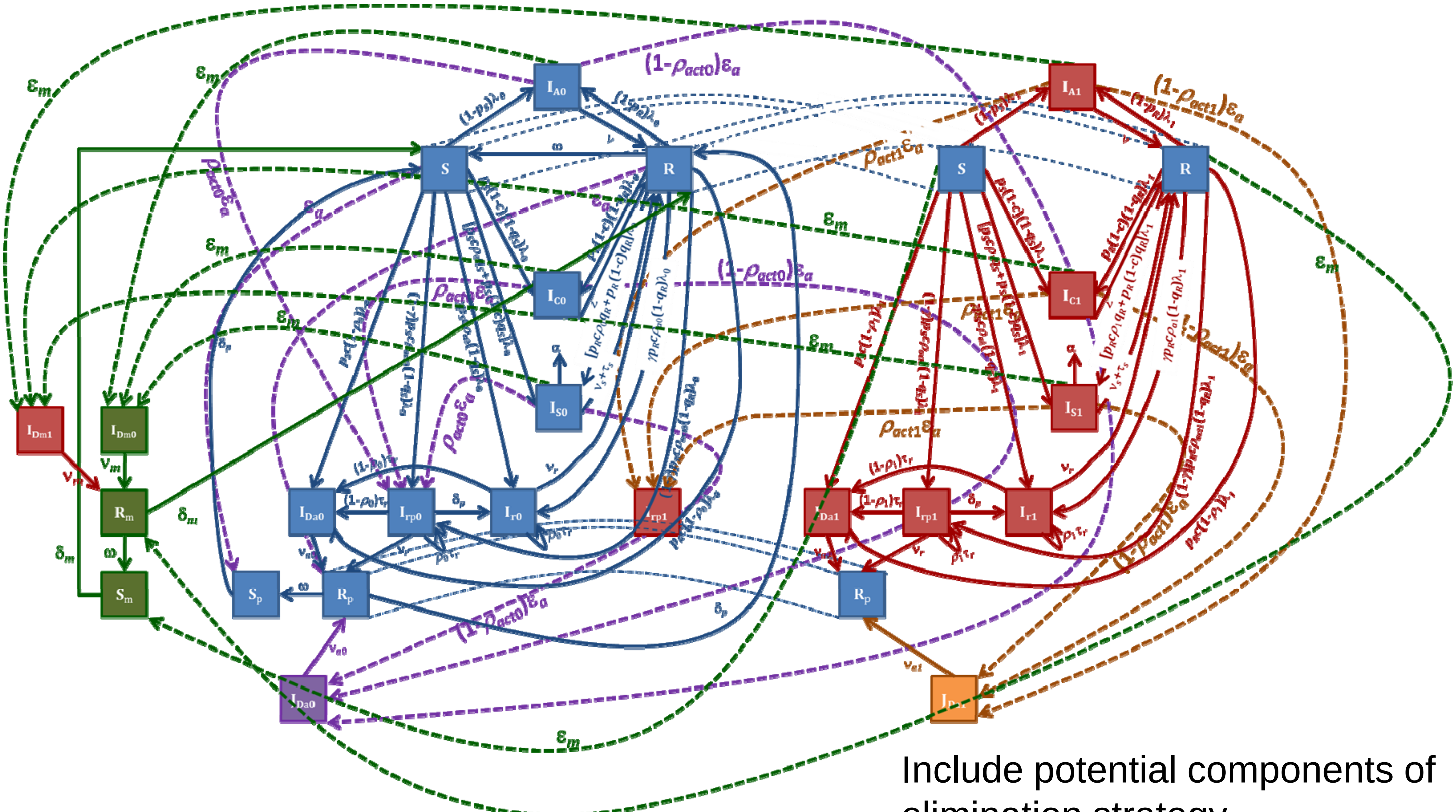
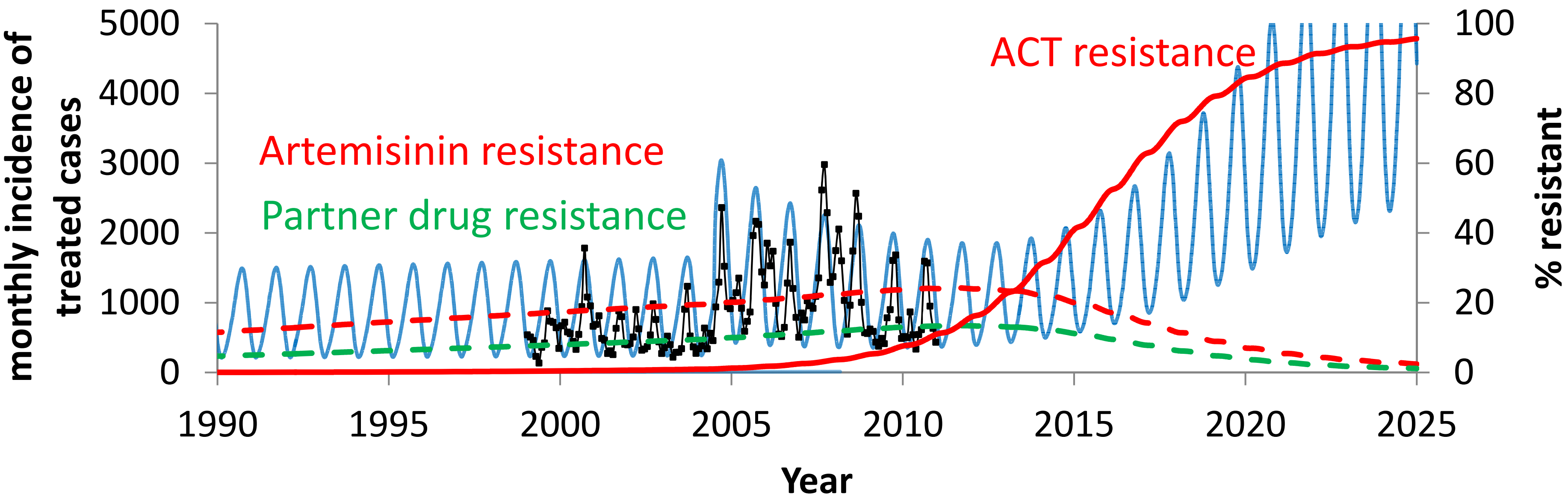
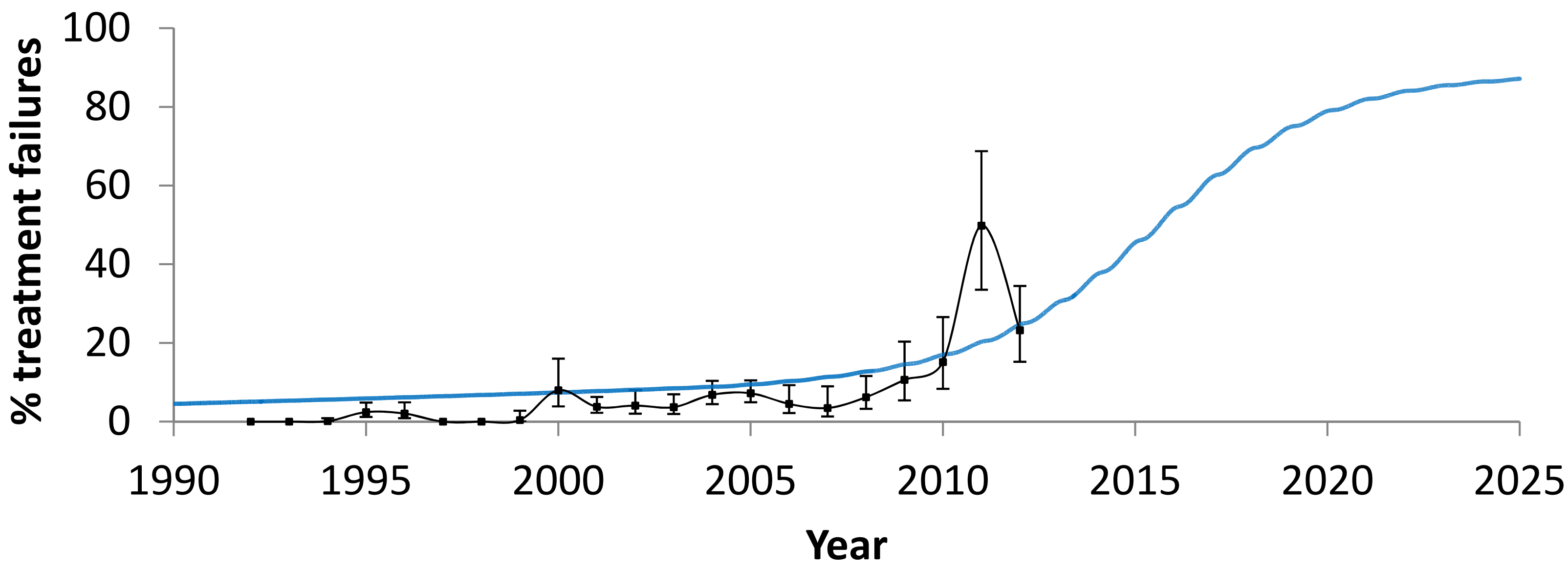
Transmission model



Include potential components of elimination strategy

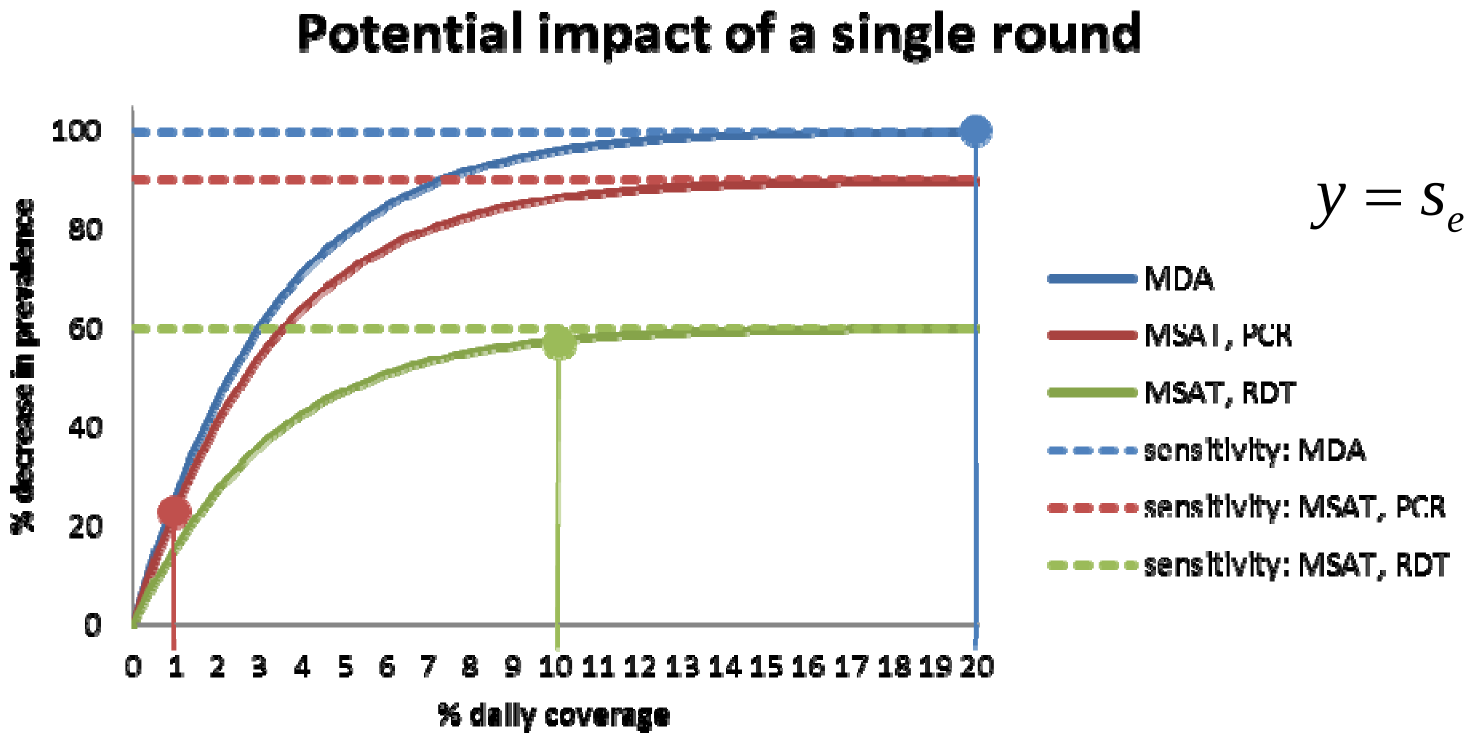
ACT resistance versus artemisinin resistance





Do Malaria Mass Interventions have enough Coverage?

- For a single round of a MDA/MSAT lasting for less than 3 months, the equation (below, right) can approximate the predicted percentage decrease, y, in parasite positive prevalence, where s_e is the percentage sensitivity of the test, c_d is the percentage daily coverage of the program and m is the duration of the round in months



$$y = s_e\left[1-\left(1-\frac{c_d}{100}\right)^{\frac{365}{12}m}\right]$$

MSAT strategy modelling

- The complex model is spatially explicit and allows for heterogeneity in transmission between patches.
- For this set of simulations, each village is an individual patch. For each simulation, the villages to be included are chosen by drawing a random line on the map for Preah Vihear defining a section of the district with a population between 40,000 and 60,000 individuals. This is then defined as the target population for elimination.
- The model assumes that this is a closed population, so the results relate to the potential for elimination under the assumption that there are no imported cases.
- Elimination is defined to have occurred when the model predicts zero infected individuals. The model simulations were run until the year 2020.

Two scenarios

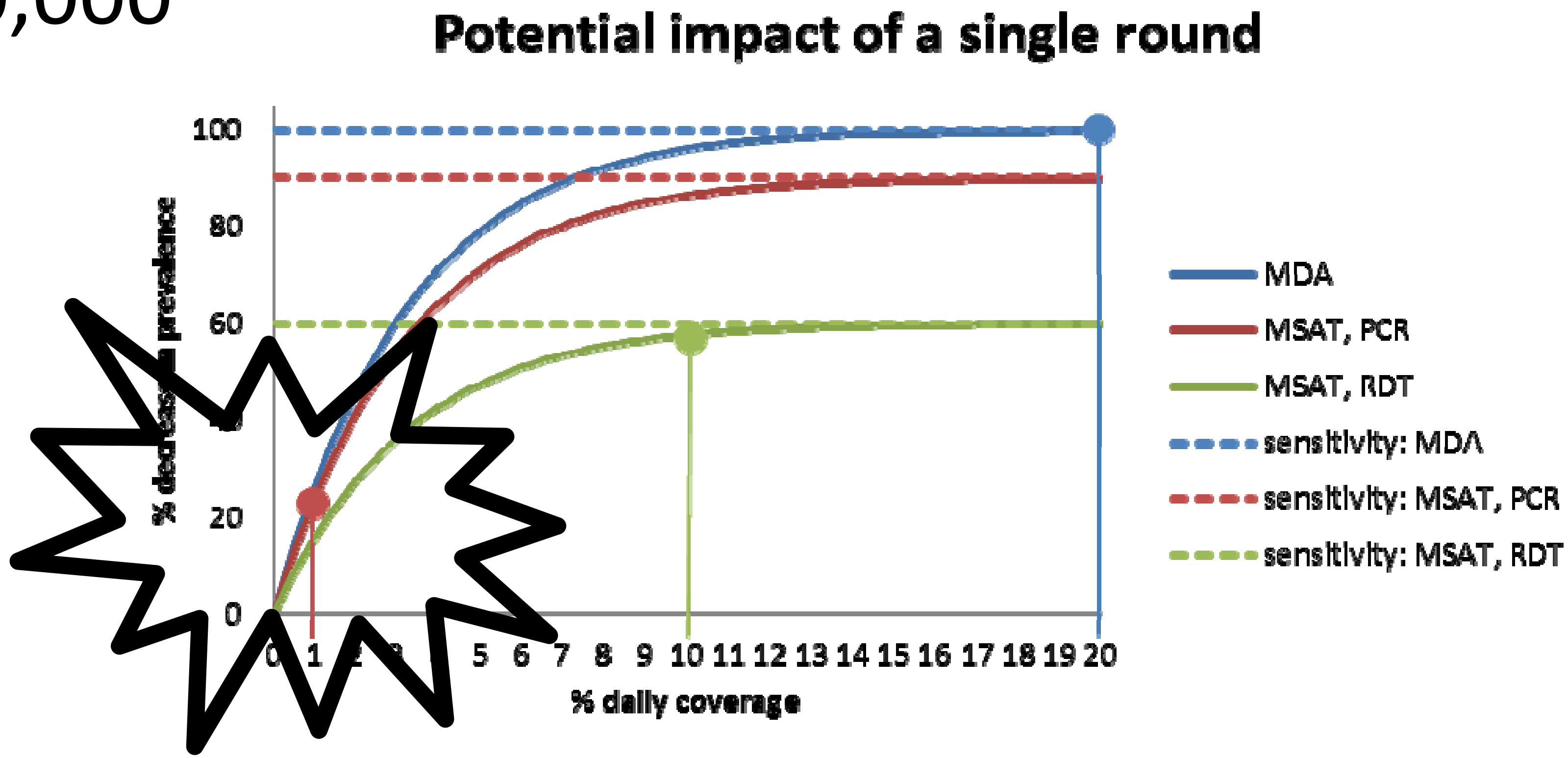
- Baseline (do nothing more) scenario
  - In this scenario we assume the number of VMWs will not increase and their efficacy will not vary over time. We assume no further distribution of bed nets. We use this scenario to compare with interventions.
- MSF MSAT strategy scenario
  - no new VMWs will be introduced
  - the MSF MSAT strategy will begin in September 2013 and continue for 3 years
  - the number of samples that can be screened in 1 day can be between 100 and 1000
  - the mean coverage of MSAT within a village is between 80% and 100%
  - the standard deviation of MSAT coverage in villages is between 1% and 20%
  - For each observation period the cumulative incidence of reported cases for each village is predicted. Then the villages are ranked by cumulative incidence of reported cases. Then the model simulates a progressive series of MSAT moving from village to village down the ranked list until the end of the observation period. The time taken to perform the MSAT for the village will depend on the population of the village. The ranked list is updated at the end of the observation period and the whole process repeated until the end of the intervention period of 3 years.

Preliminary results

- In the baseline “do nothing more” scenario, for 852 simulations, the probability of success is predicted to be 6%.
- In the MSF strategy scenario, for 2132 simulations, the probability of success is predicted to be 18%.

How can MSAT using a test with high sensitivity lead to such a poor prediction?

- The daily turnover of tests is so low that the effective coverage on any day is only 300/50,000



How can the chances of success be improved?

- Increase the ratio of daily turnover of tests to target population by either
  - Increasing the number of tests per day (to 700)
  - Reducing the target population (to 20,000)