Quantifying Weather and Climate Impacts on Health in Developing Countries (QWeCI)

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Malaria model development: First principles

OJ Botai
University of Pretoria
Joel.botai@up.ac.za

O.J. Botai[1], H. Rautenbach[1], J. M. Olwoch[2], A.M. Kalumba[1], P.Tsela[1], A. Adeola[1], O.M. Adeola[1], F.W. Nsubuga[1]

[1]Department of Geography, Geoinformatics and Meteorology, University of Pretoria, Hatfield, South Africa
[2]South African Space Agency (SANSA), Earth Observation Directorate, South Africa

SEVENTH FRAMEWORK PROGRAMME

UNIVERSITEIT VAN PRETORIA
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Theme 2-1: Additional expected deliverables

- **Dynamic malaria model runs + development of new malaria model (Matlab+Mathematica)**
  - Mr Kibii Komen (LLM)
  - Mr Adeola (new generic model @ UP: OJ Botai) **+ VECTRI**
- **Skill of dynamical predictions for southern Africa**
  - Prof. Hannes Rautenbach and Mr Robert Maisha used various cumulus parameterisation schemes in the WRF model on a 9km resolution over South Africa.
  - The different simulations were verified against observations
  - A most suitable scheme was selected to simulate the past 40-years of daily precipitation and other atmospheric variables.
  - A journal paper has been completed and has already been submitted for review.

Introduction

- Gospel:
  - Application of deterministic(& also stochastic) mathematical models to understand malaria transmission in human population is as ancient as the malaria disease itself.
  - The success of using this models to describe the host-parasite biology (spread & transmission) is constrained by global change: changing environmental & social-economic conditions
  - i.e., due to climatic changes (global warming), malaria exhibits an implicit association: changes in climatic parameters linked to changes in the parameters that characterise the malaria prevalence
  - Consensus:
    - Spatial spread of malaria is not well understood c.f. the temporal evolution
    - Very few existing malaria models

Introduction

- In general, the spread of malaria has historically been described by:
  - Reaction diffusion equations (see e.g., Murray, 1977; 1989) with diffusion parameter D (e.g., SIR model):

$$\partial_t S = -rIS + D\nabla^2 S$$

$$\partial_t I = I(r-a) + D\nabla^2 I$$

  - Multi-path ODE
    - Population sample space is divided into population sub-spaces (patches) and then allow inter-patch infective processes to take place

Introduction

- Modelling paradigm motivated from
  - Ngwa & Shu (2000)->Chitnis et al., (2006)-> Parham-Michael (2010)-> Gao & Ruan, (2012) & Tompkins & Ermert, 2013)

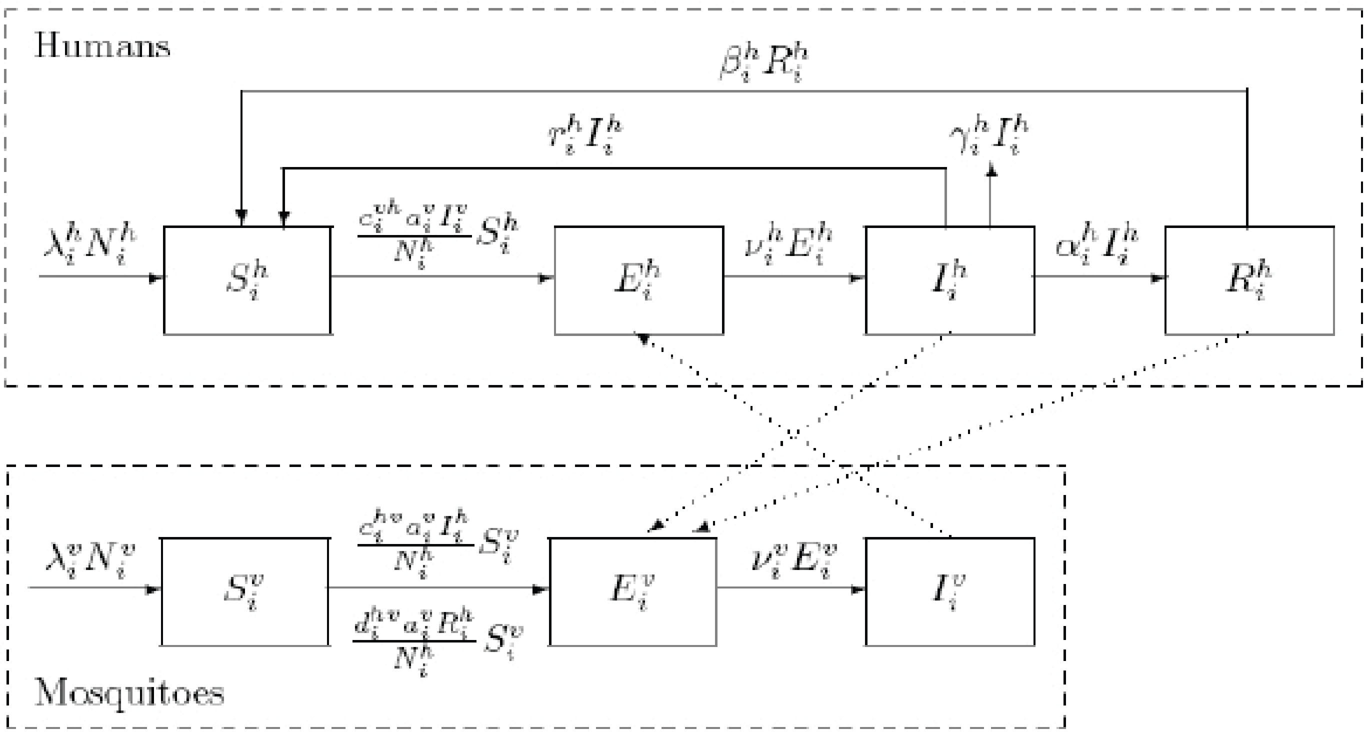

Fig 1: Malaria borne-vector model. Source Gao & Ruan, 2012)

Drivers

$$\lambda \to \lambda_{|R,T}$$

$$a \to a_{|T}$$

$$\tau_{|\{m,h\},T} ; l_{m,T}$$

$$\nu_h = G\{\mu\alpha\beta A_i \eta(t,\Gamma)\};$$

$$\nu_v = \alpha\zeta G(t)\eta$$

$$\eta = \chi\Gamma(\Delta t);\ \chi = \begin{cases} 1 & \text{if } \Gamma \geq \tau \\ 0 & \text{else} \end{cases}$$

- Adult mosquito bite rate per day
- Biting rate of mosquito on human
- Latent period for mosquitoes & humans
- Survival prop. of infected mosq. over incubation periods,
- Daily survival prop. for eggs, larvae & pupae
- Duration of eggs, larva & pupae

Model specification

- Deterministic approach
  - Numerically solve system of equations
  - Perform sensitivity & bifurcation analysis
  - Perform simulations
    - N/B: integrity of the system during simulations?? (sensitivity analysis)
- Stochastic approach
  - Use Gillespie algorithm
- Multi-path option
  - This is the core of the new model!

Modelling phases

- Phase 1: Algorithm design & development

Done BUT!

- Phase 2: Testing

In progress

- Phase 3: Validation

After July