

Simulating malaria transmission in the current and future climate of West Africa

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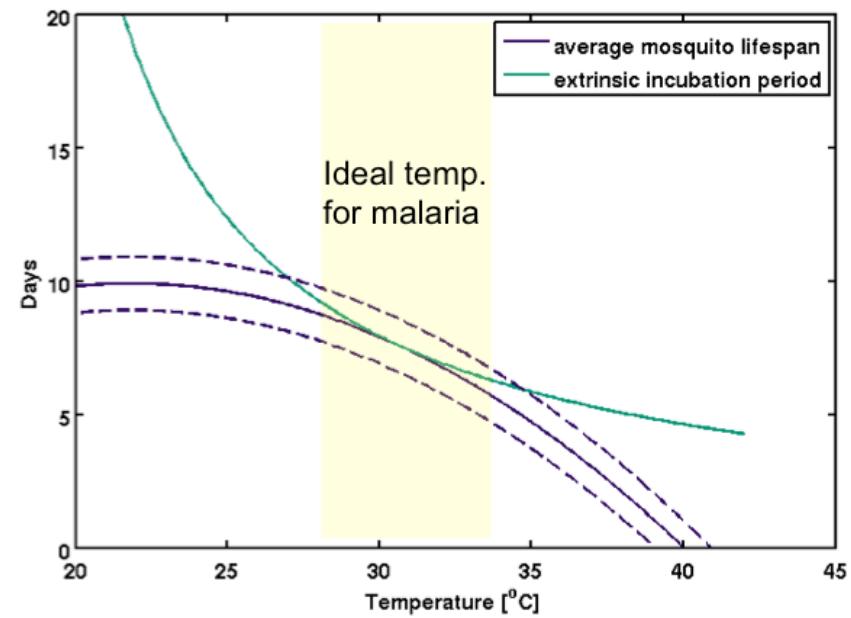
AGU Fall Meeting 2015

Relationships between malaria and climate

rainfall



temperature

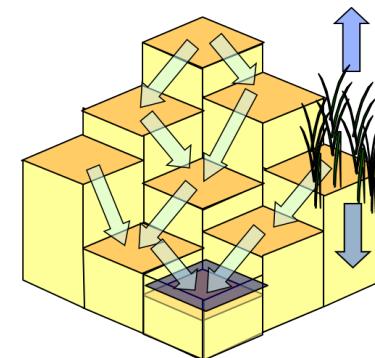


Hydrology

- Processes
 - Infiltration
 - Evaporation
 - Overland flow
- Key parameters
 - Soil
 - Topography
 - Vegetation

Climate forcing

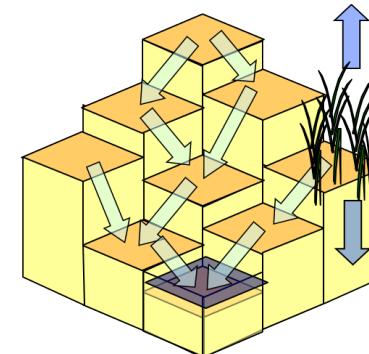
Water pools



Hydrology

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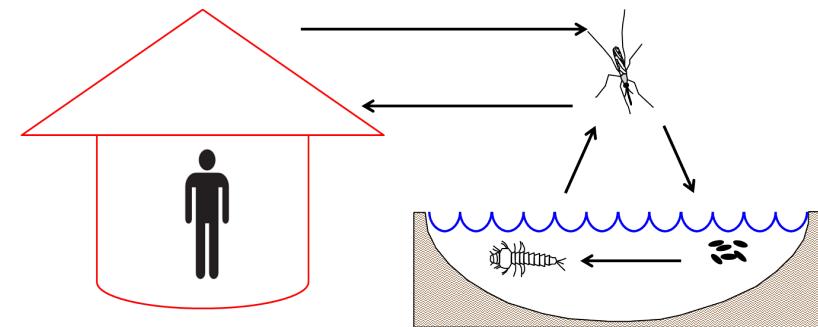
Climate forcing



Entomology

- Processes
 - Flight
 - Biting
 - Ovipositing
 - Development
 - Death
- Key parameters
 - Mosquito growth and death rates
 - preferences for biting, resting, ovipositing behavior

Water pools

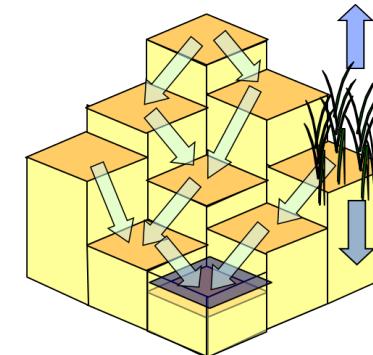


Mosquito bites

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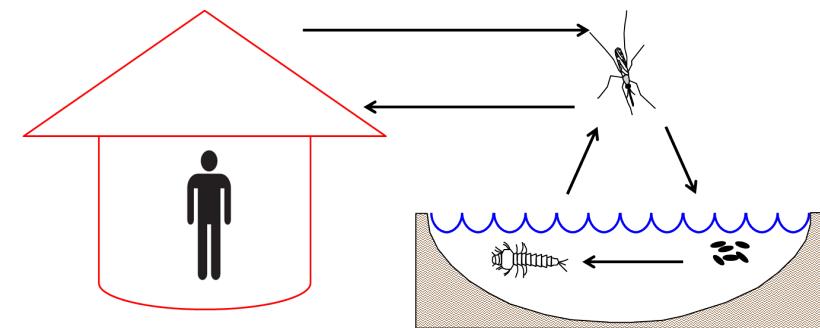
Climate forcing



Entomology

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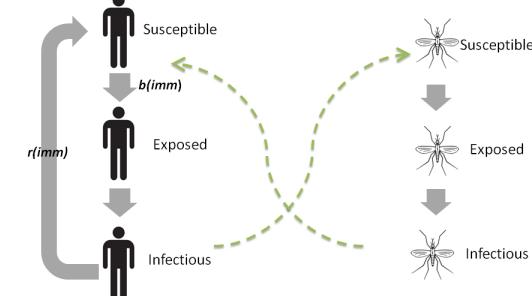
Water pools



Malaria Transmission (Immunology)

- Processes
 - Human infection
 - Disease clearance
 - Acquired immunity
 - Transmission to mosquito
- Key parameters
 - Clearance rate
 - probability of transmission
 - rate of acquiring immunity

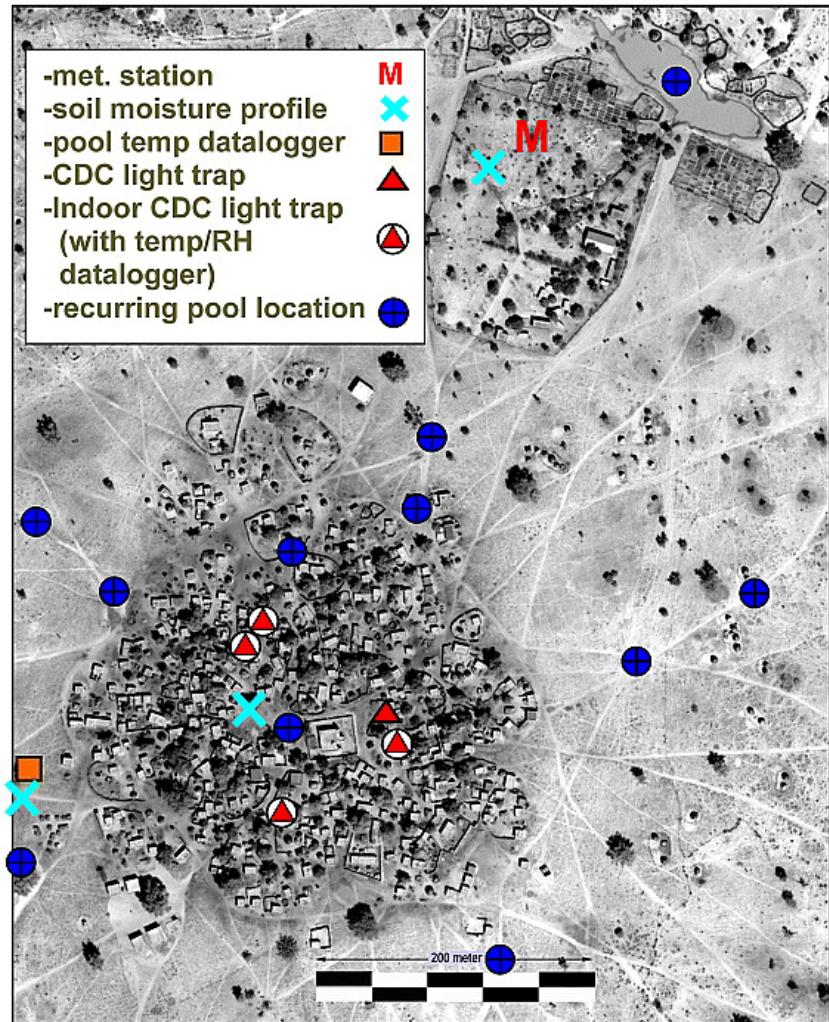
Mosquito bites



Malaria prevalence

Model development and validation

- ▶ Extensive field campaign
- ▶ Model tested against numerous observational data sources
 - ▶ From field site
 - ▶ Soil moisture
 - ▶ Water pool location, depth & temperature
 - ▶ Larval mosquito counts
 - ▶ Adult mosquito counts
 - ▶ Malaria prevalence
 - ▶ Elsewhere in Africa
 - ▶ Mosquito biting rate
 - ▶ Malaria prevalence

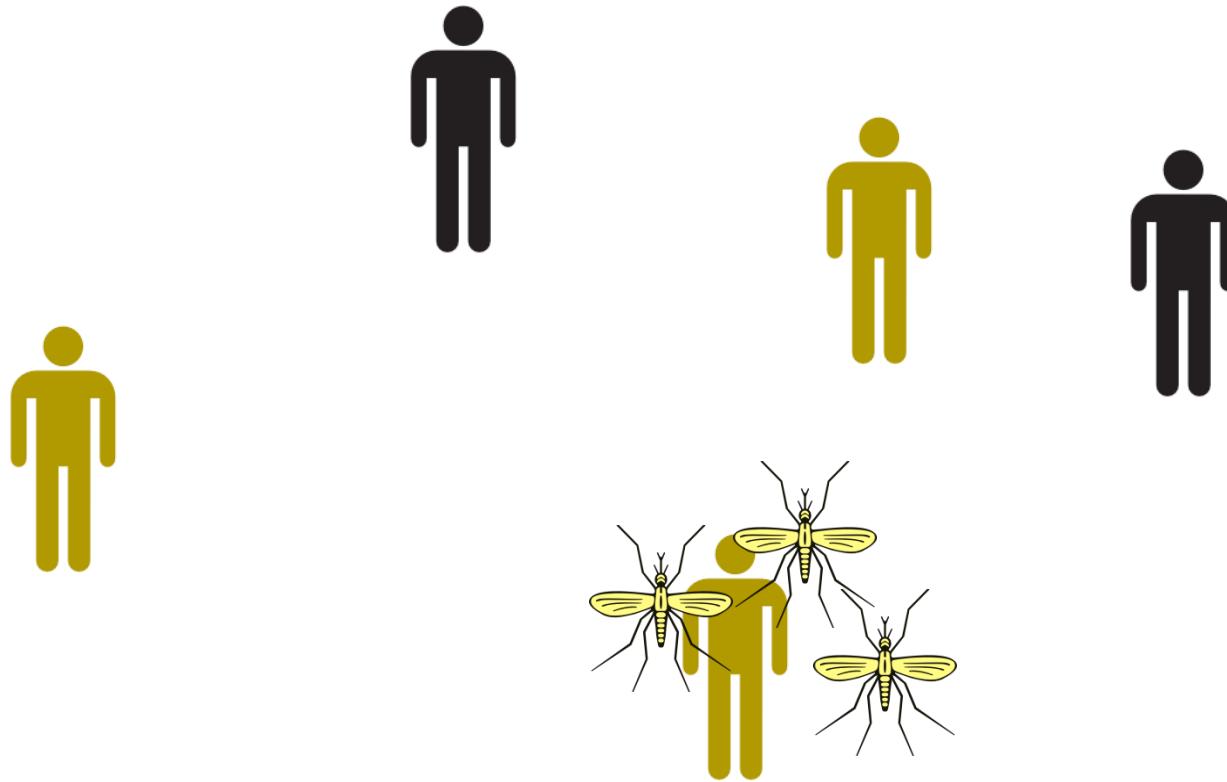


Bomblies et al. *WRR*, 2008; Bomblies et al. *Malaria Journal* 2009;
Yamana et al. *Parasites & Vectors* 2013; Yamana et al. *in review*

A woman in a traditional patterned dress and headwrap carries a large blue jerrycan balanced on her head. She is walking through a dirt path in a rural area with mud-brick buildings and thatched huts in the background. The scene is bright and sunny.

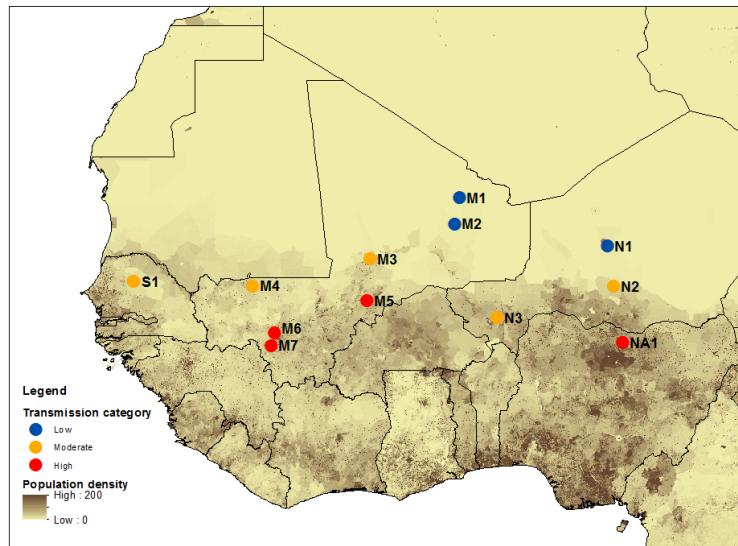
Predicting impacts of climate change on
malaria transmission

Basic reproduction number R_0



- ▶ Number of **people infected** from a single infected person over the duration of his disease, assuming an entirely susceptible population

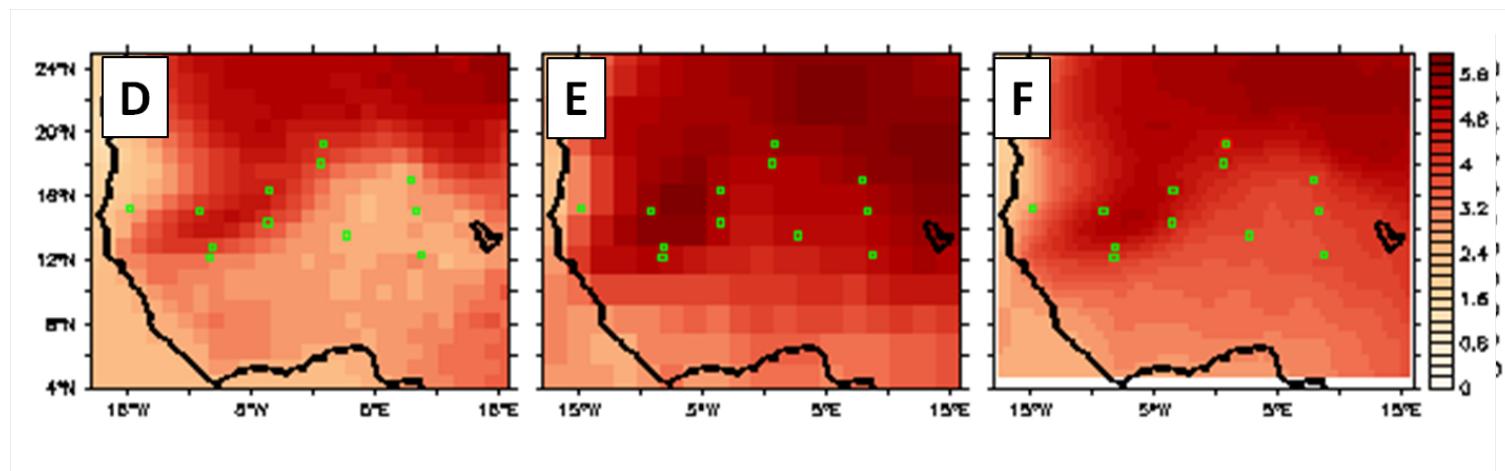
Classification of sites by simulated R_0 in current climate



- ▶ **Low transmission**
 - ▶ $R_0 < 1$ most years
 - ▶ Disease can be eliminated, but you could have a small epidemic if conditions were favorable
 - ▶ People have low immunity
- ▶ **Moderate transmission**
 - ▶ $1 < R_0 < 10$
 - ▶ Prevalence fluctuates
 - ▶ Moderate immunity levels
- ▶ **High transmission**
 - ▶ $R_0 > 10$ almost all years
 - ▶ Prevalence consistently high
 - ▶ High immunity levels

Predicted change in climate by 2070-2100 RCP8.5

Temperature

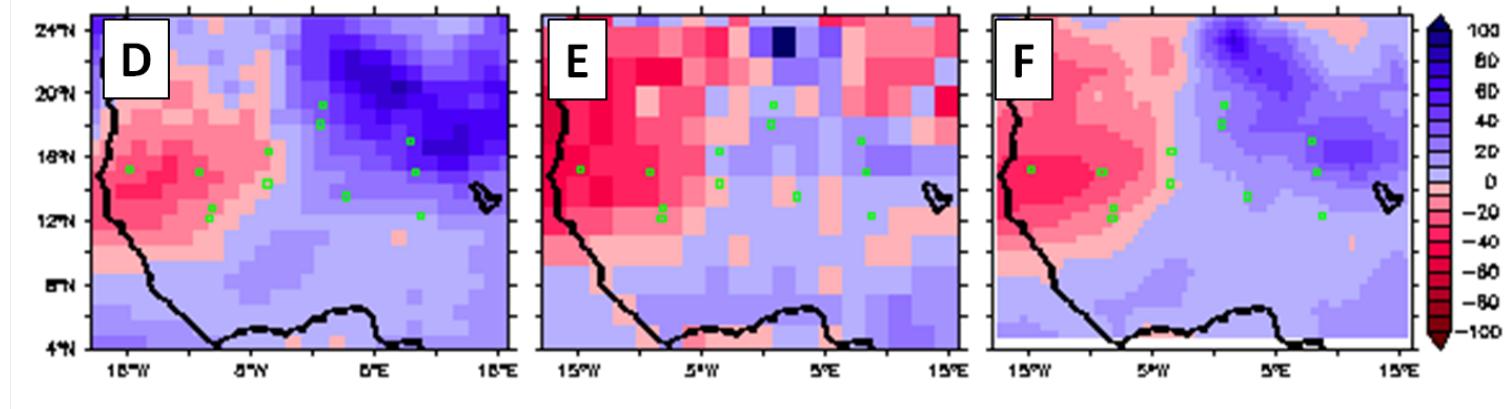


CCSM4

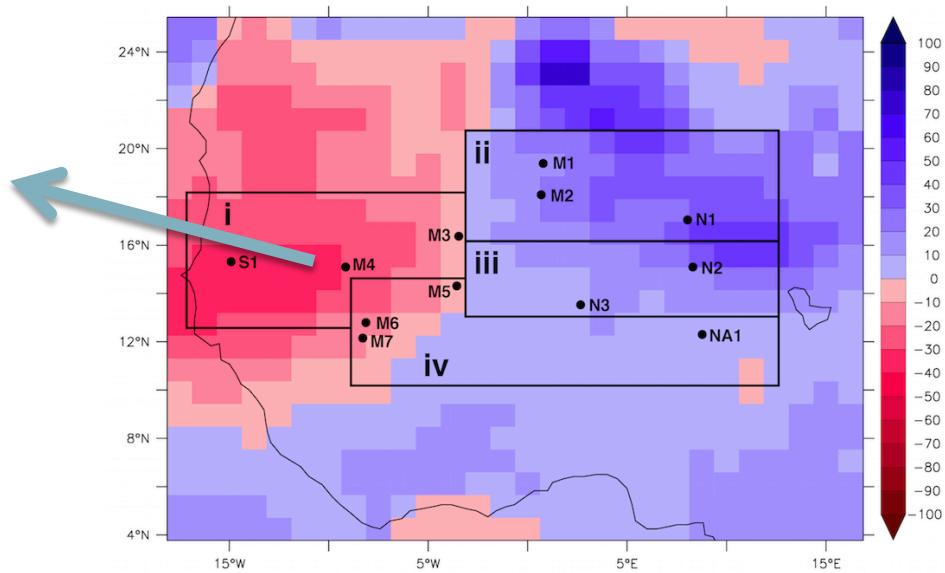
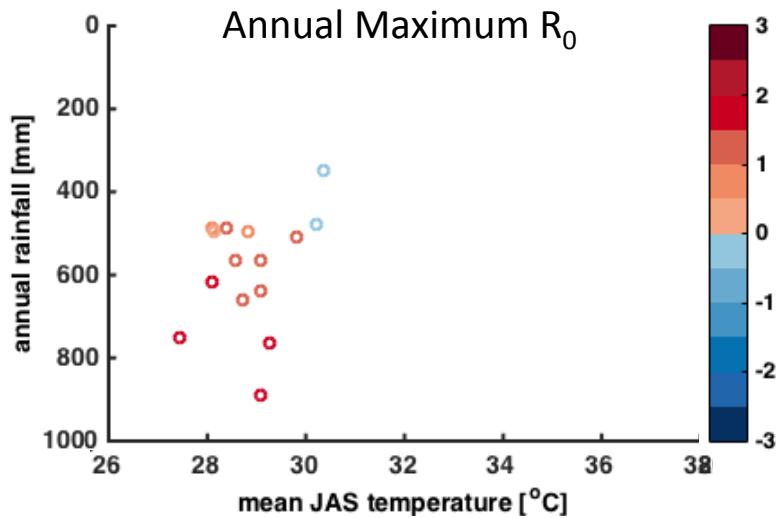
MPI

Average

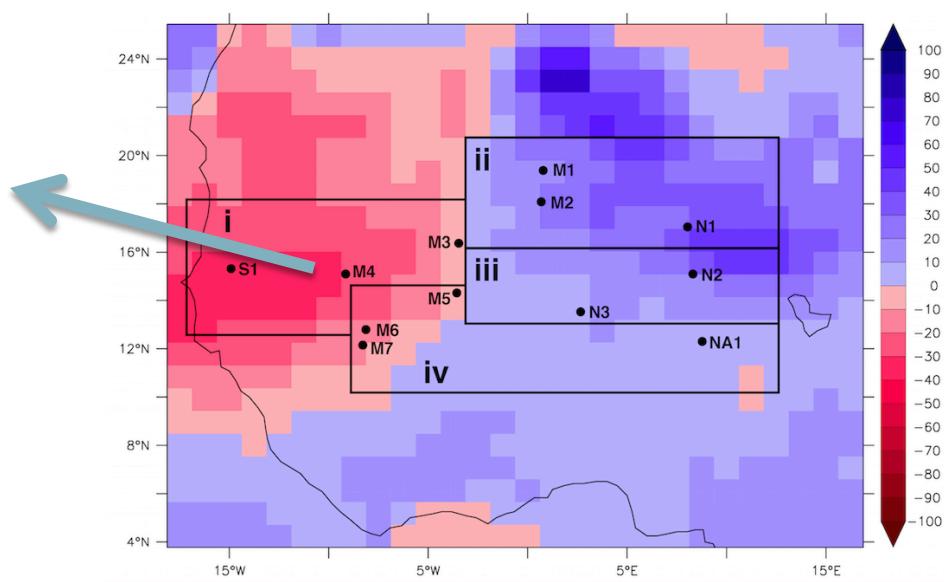
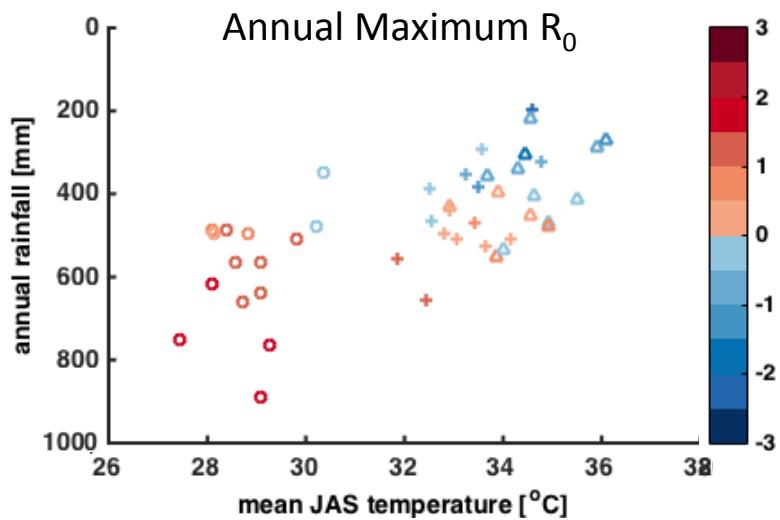
Rainfall



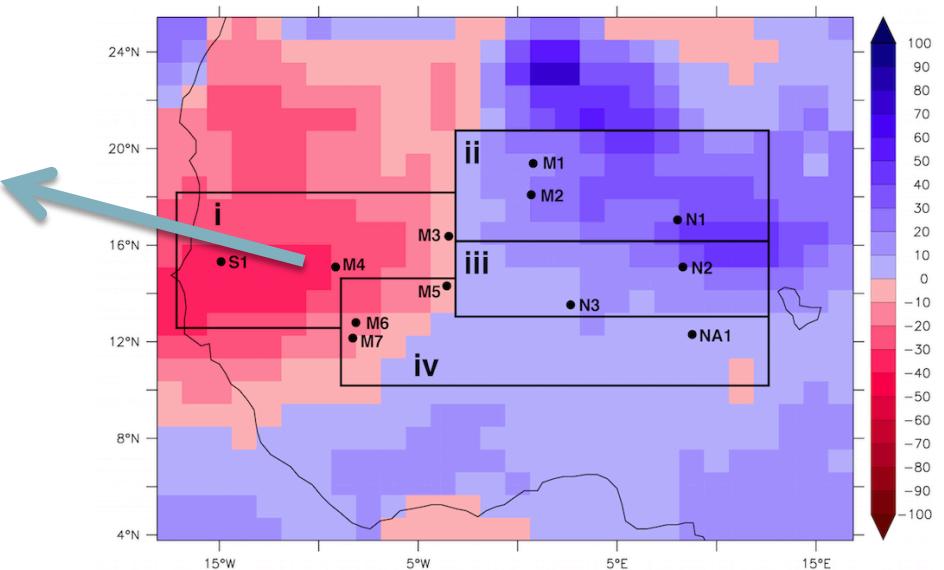
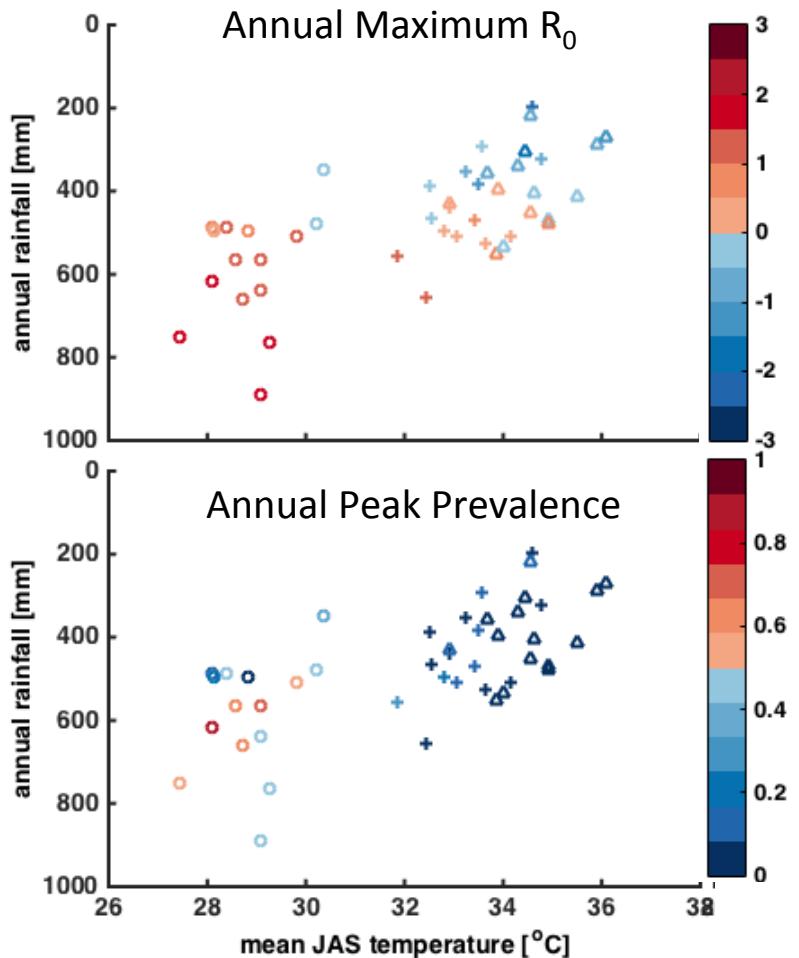
R_0 baseline climate 1975-2005

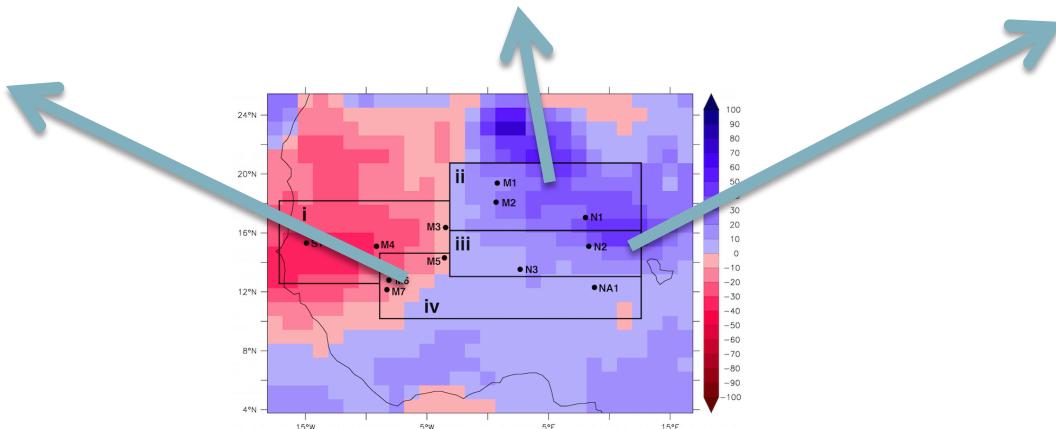
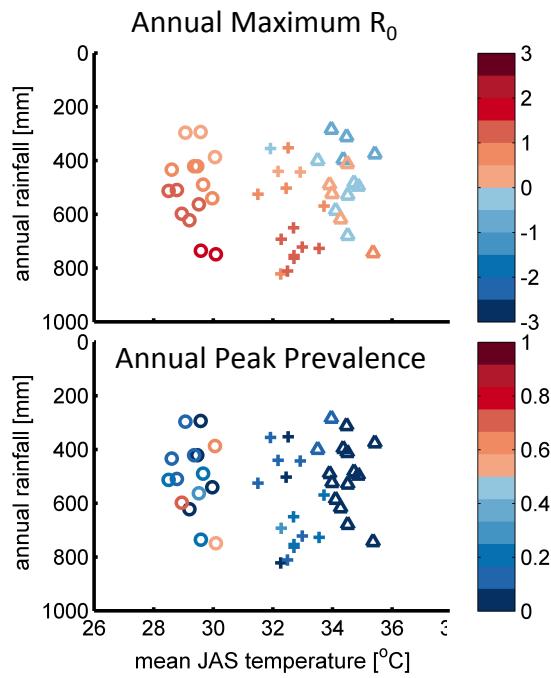
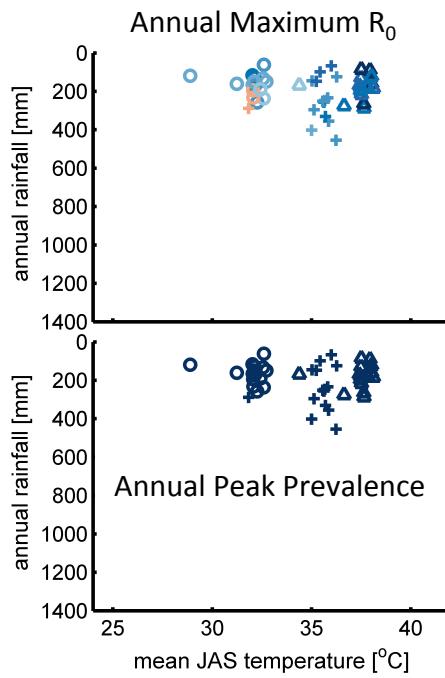
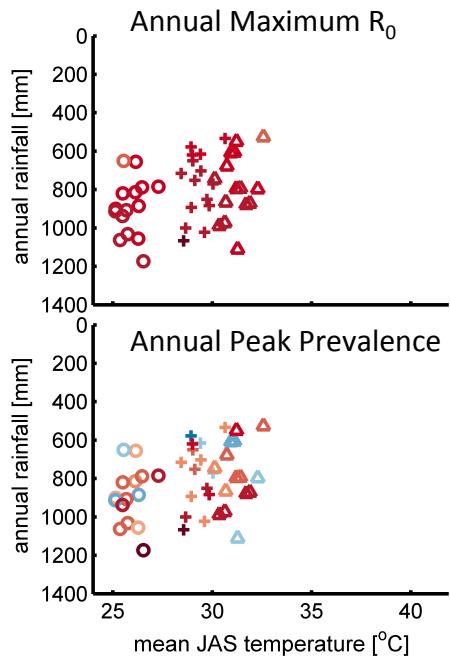


R_0 1975-2005 and 2070-2100



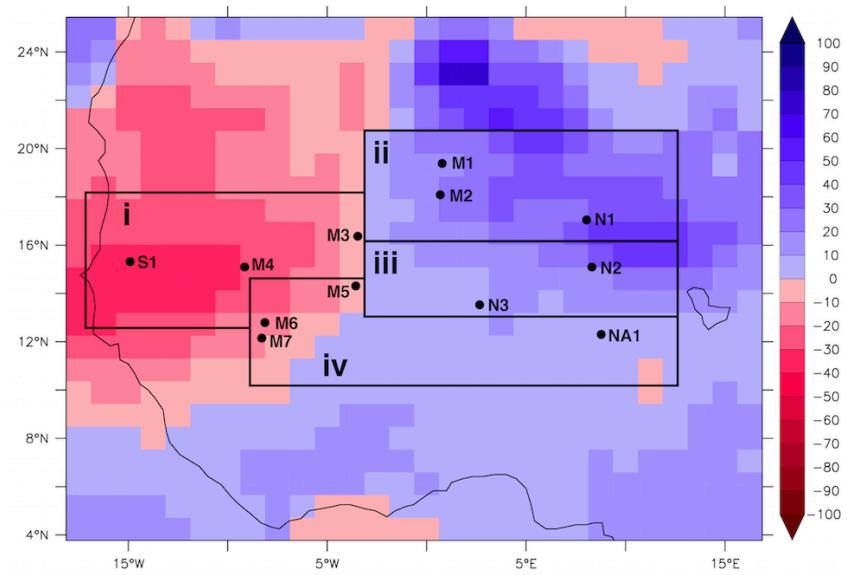
R_0 and Prevalence R_0 1975-2005 and 2070-2100





Conclusions

- ▶ Climate change impacts vary by sub-region, but overall, no major increases expected
- ▶ Sub-region i:
 - ▶ Hotter and drier
 - ▶ Less malaria
- ▶ Sub-region ii:
 - ▶ Wetter but too hot for mosquitoes
 - ▶ Minimal change
- ▶ Sub-region iii:
 - ▶ Hotter and wetter
 - ▶ Small changes, uncertain
- ▶ Sub-region iv:
 - ▶ Good conditions for malaria
 - ▶ Minimal change



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Ibrahim Arzika
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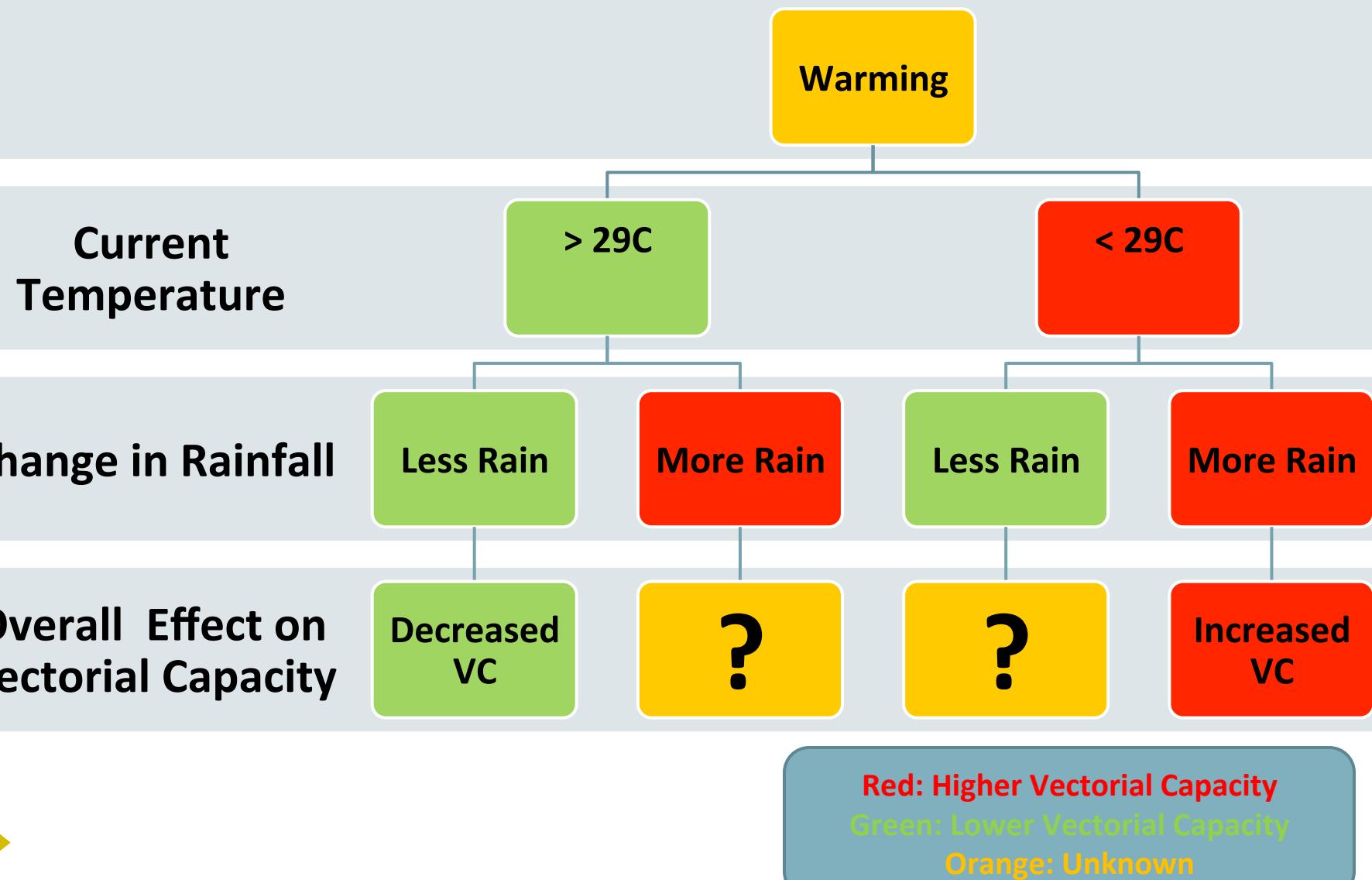




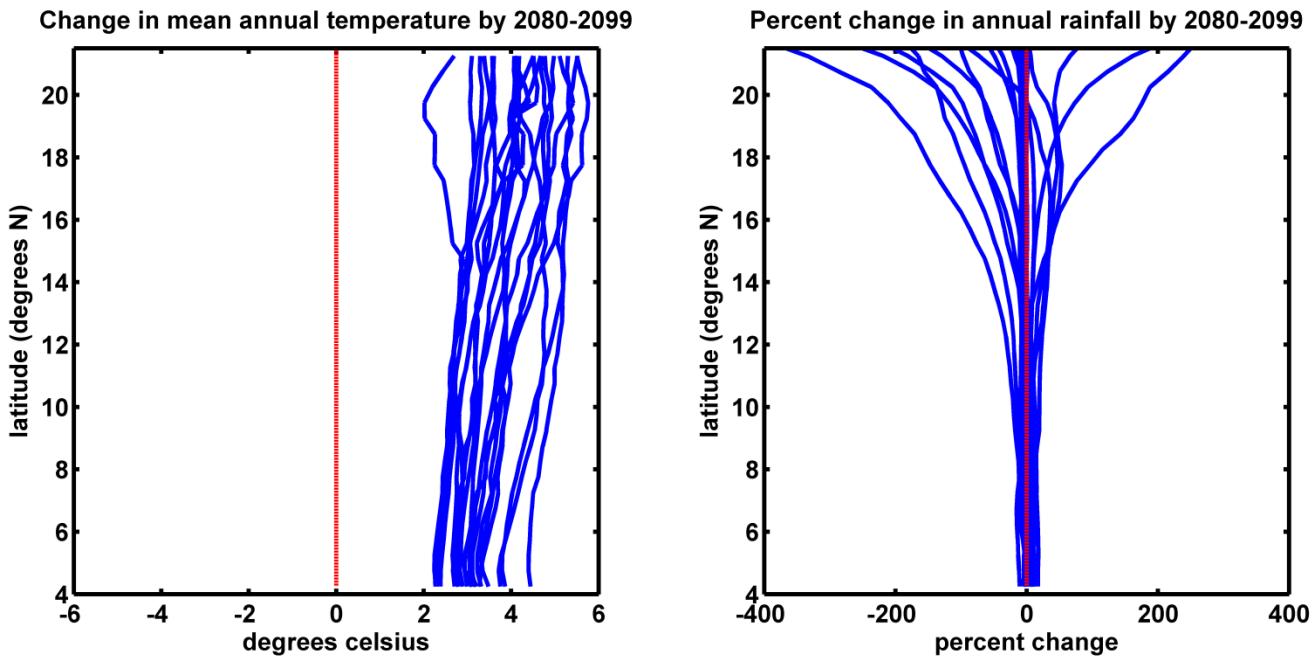
Key terms

- ▶ **Vectorial capacity:** Number of **infectious bites** resulting from a single infected person **per day**
- ▶ **Basic reproduction number (R_0):** Number of **people infected** from a single infected person over the duration of his disease
- ▶ **Entomological inoculation rate:** Number of **infectious bites** per person per unit time
- ▶ **Parasite prevalence:** Percentage of the population infected by the plasmodium parasite

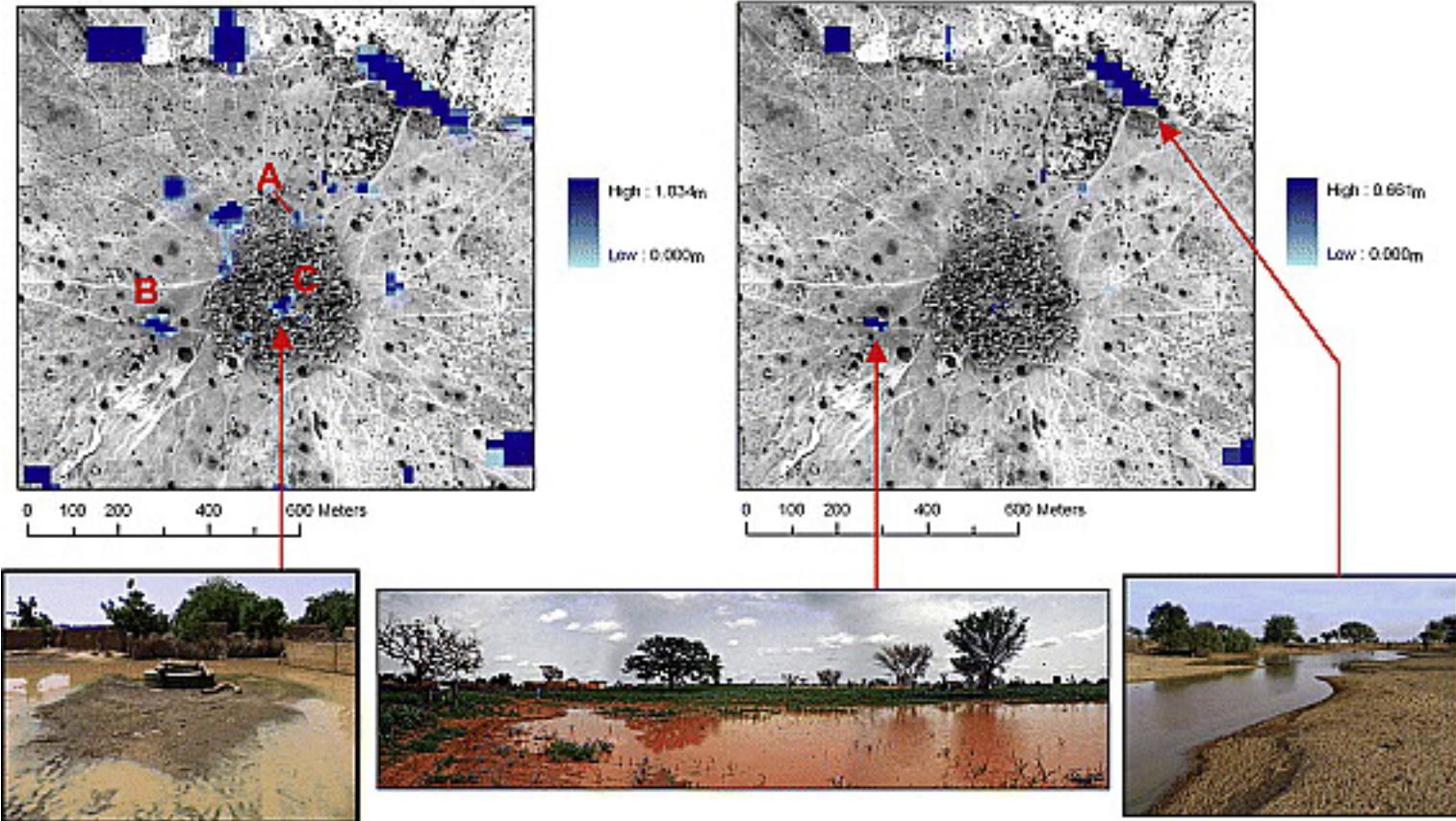
Expected effect of Climate Change



Climate change predictions



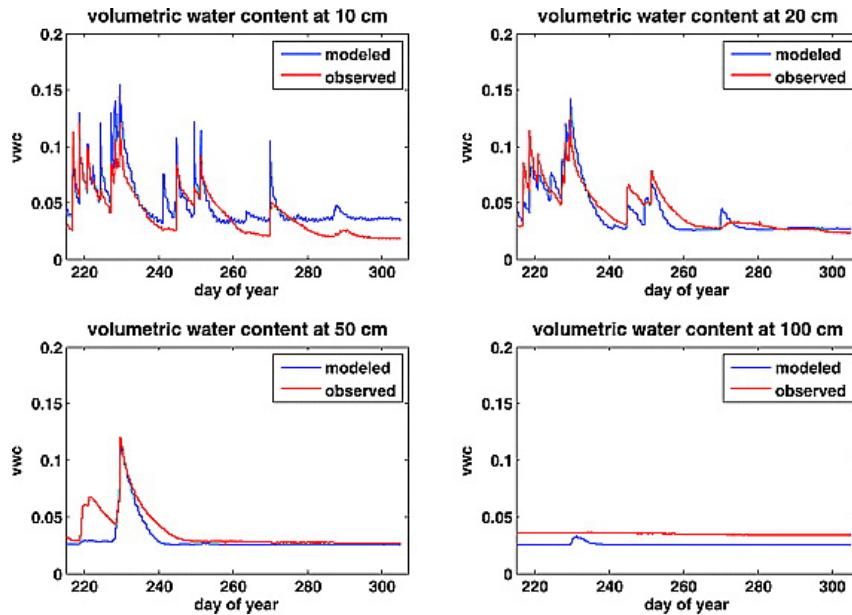
Banizoumbou & Zindarou : simulated vs observed



Bomblies et al. , *Water Resources Research*, 2008, *Malaria Journal* 2009

Banizoumbou & Zindarou : simulated vs observed

Soil moisture



Mosquitoes

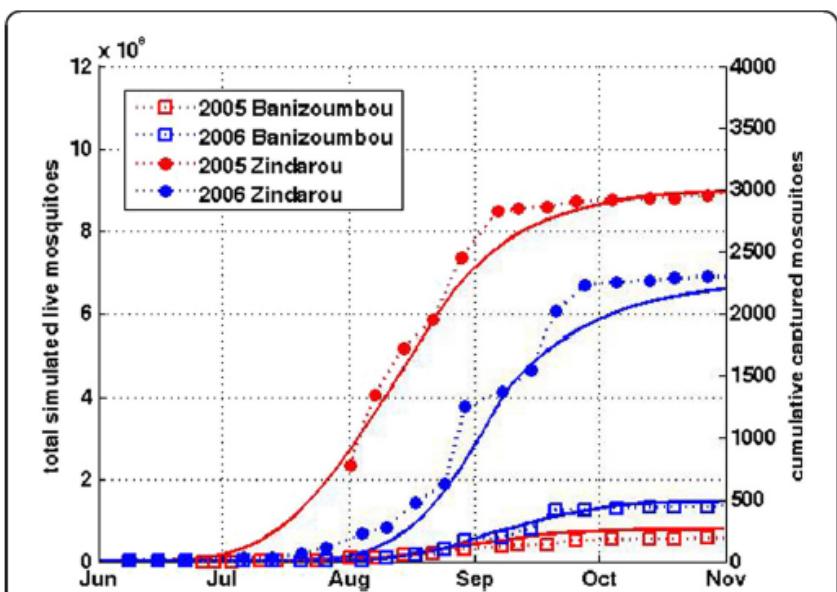
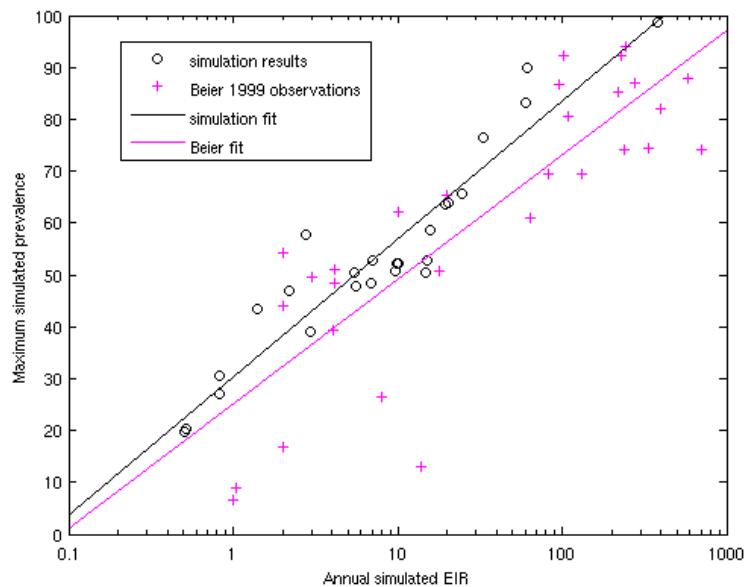


Figure 3 (From Bomblies et al., [30]) Modeled and observed *Anopheles gambiae* mosquito abundance in Banizoumbou and Zindarou. Mosquito abundance is very different in the two similarly sized villages, because of local hydrological differences. This is evident in the light trap captures (markers with dashed lines) and the simulation results (solid lines).

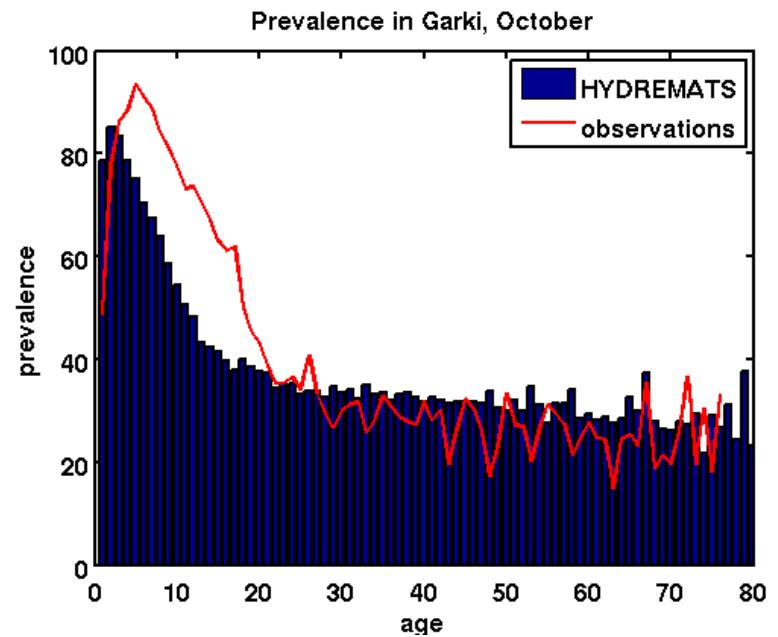
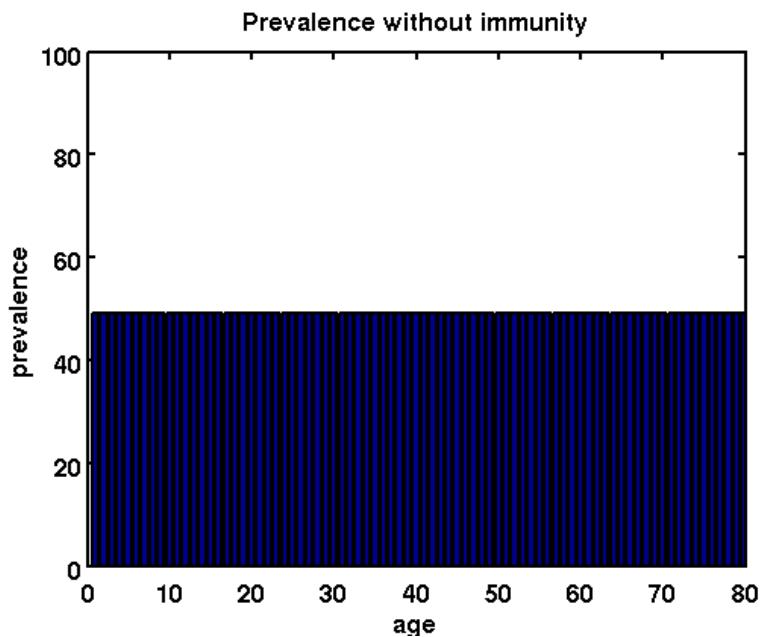
Simulated relationship of EIR vs Prevalence compares well with observations



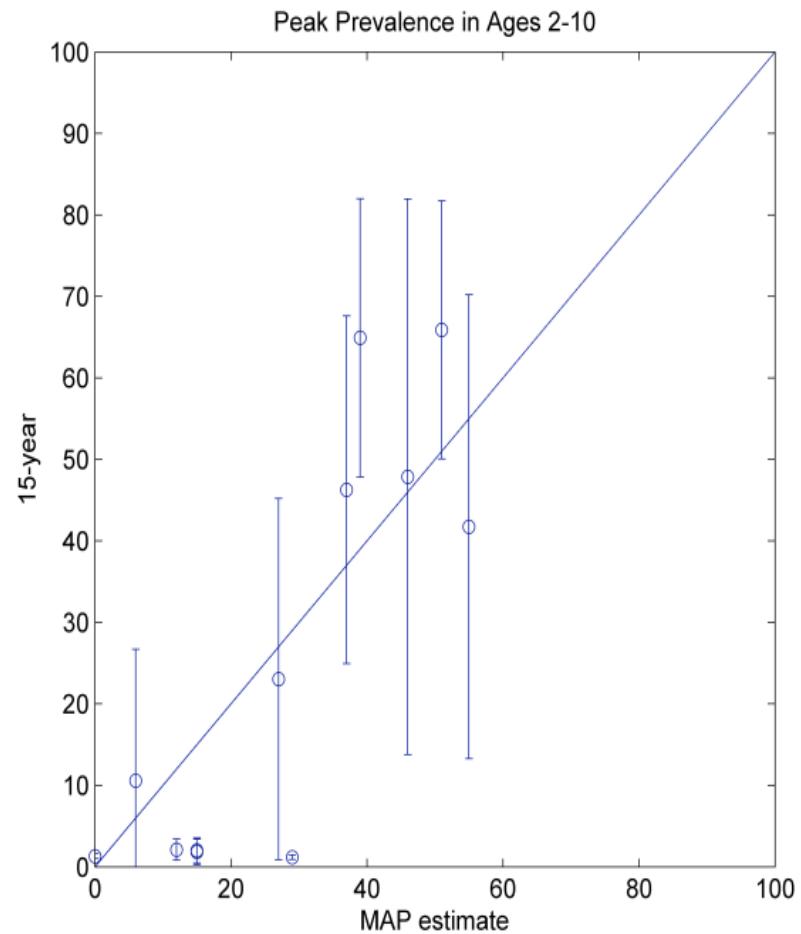
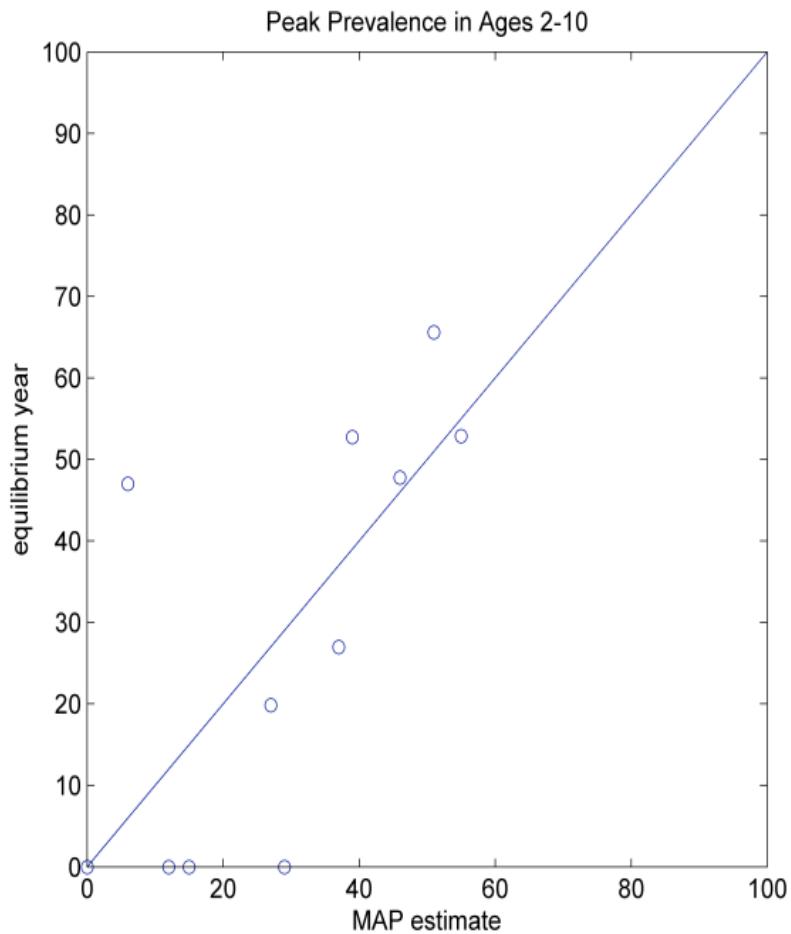
Adapted from Beier et al.

- ▶ Compiled published pairs of data on infectious bites (EIR) and malaria prevalence from 31 sites across Africa
 - ▶ Kenya, Ethiopia, Tanzania, Republic of Congo, Burkina Faso, Senegal
- ▶ Links entomology to immunology
- ▶ Fundamental relationship, independent of location or ecoclimate zones

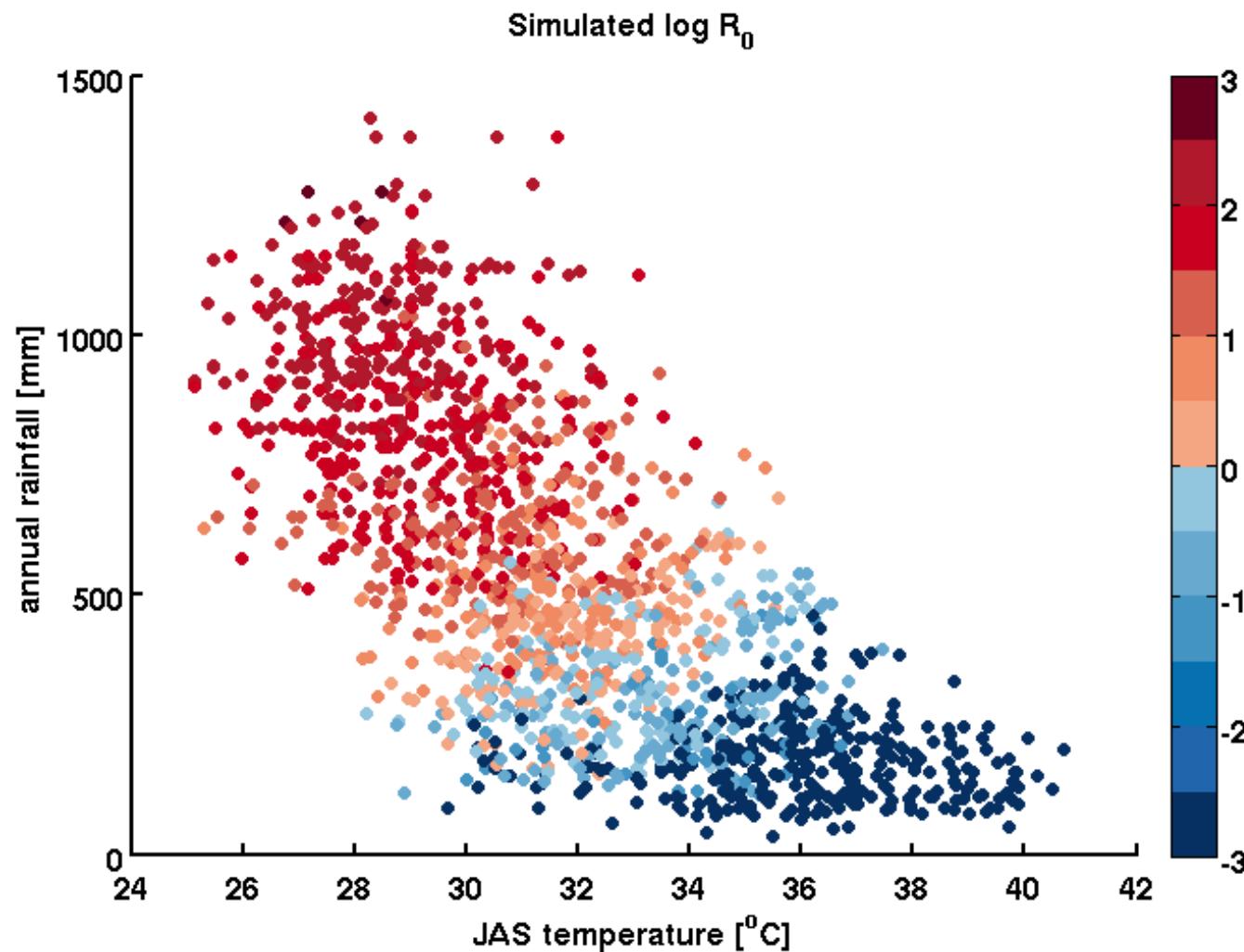
Garki prevalence by age



Comparison to MAP estimate



R₀



Prevalence

