Applications of weather prediction and climate modeling to health: An example system for malaria

climate anomalies | disease models | human movement | machine learning | decision processes

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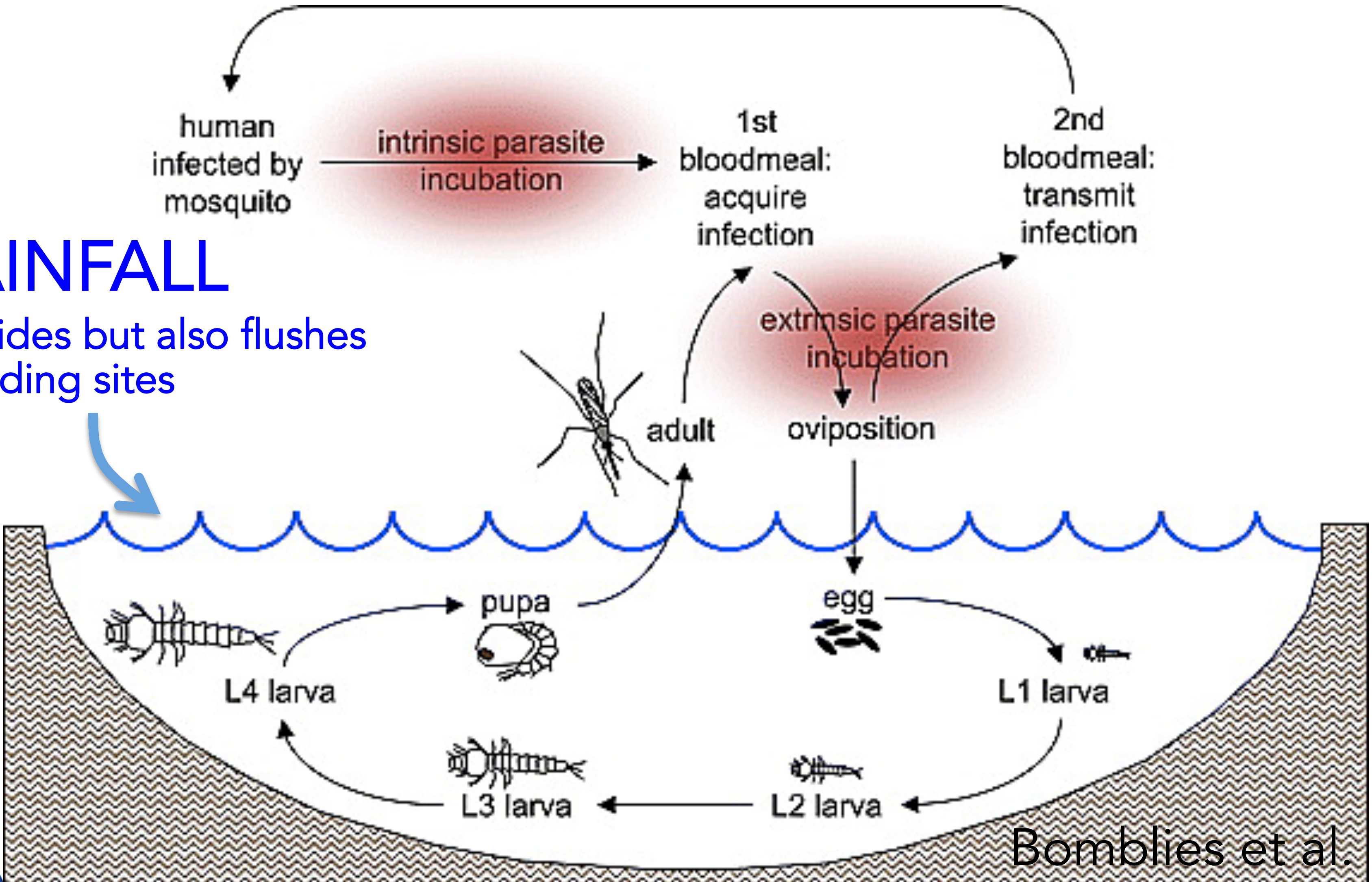
TEMPERATURE

Warmer temperatures speed up parasite, larvae and egg development
High temperature impact mortality of vector (adult and larvae)

RAINFALL

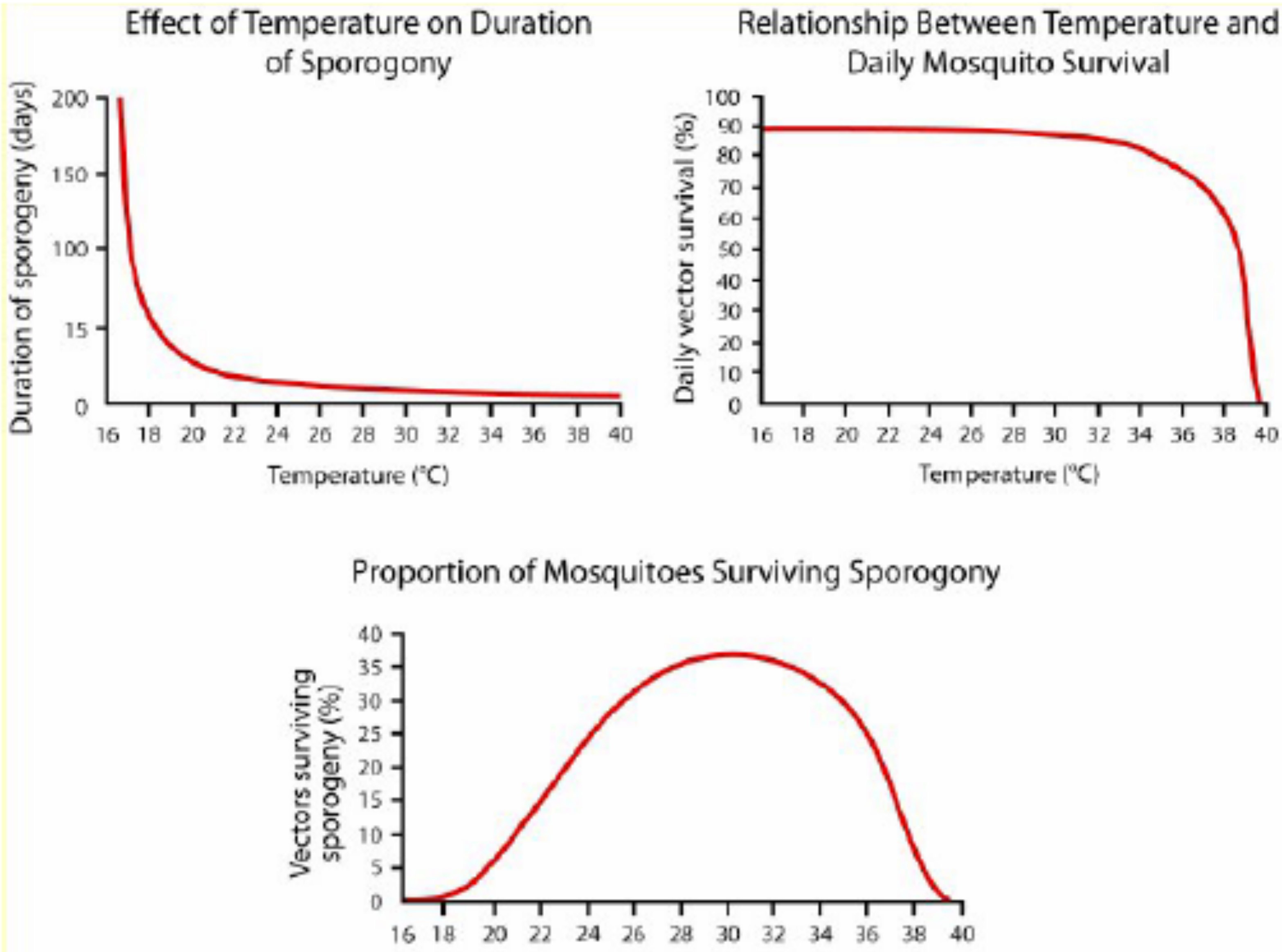
Provides but also flushes breeding sites



Bomblies et al.

MALARIA CLIMATE SENSITIVITIES

Sporogonic cycle

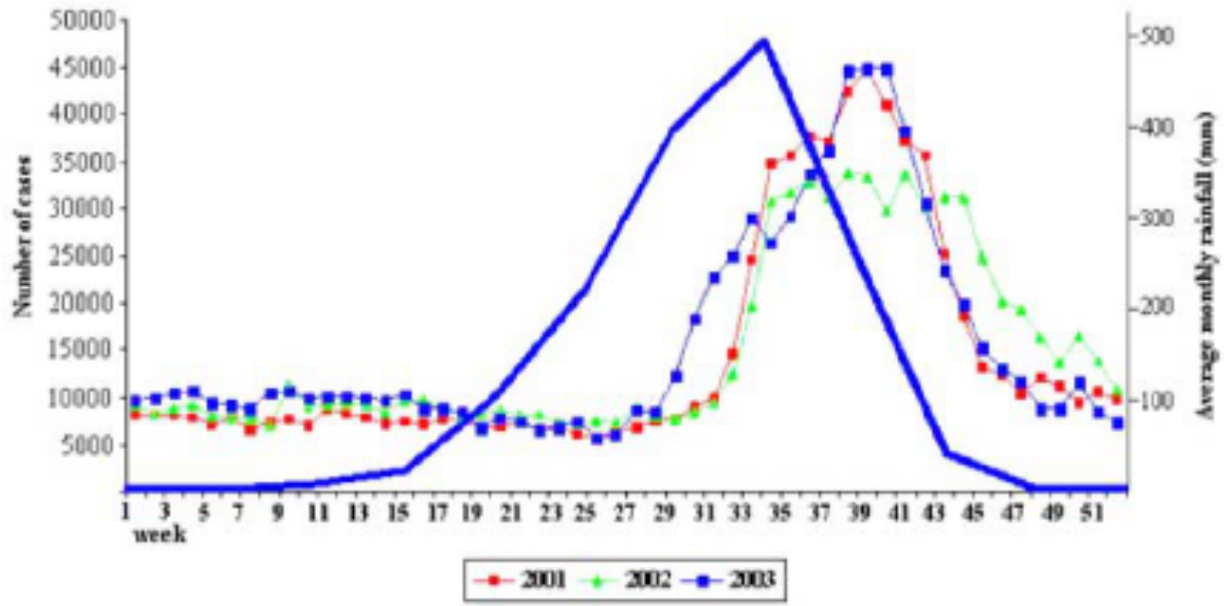


Craig et al 1999

Rainfall

- Water required for breeding.
- Anopheles Gambiae prefers natural sunlit puddles.
- highly nonlinear relationship

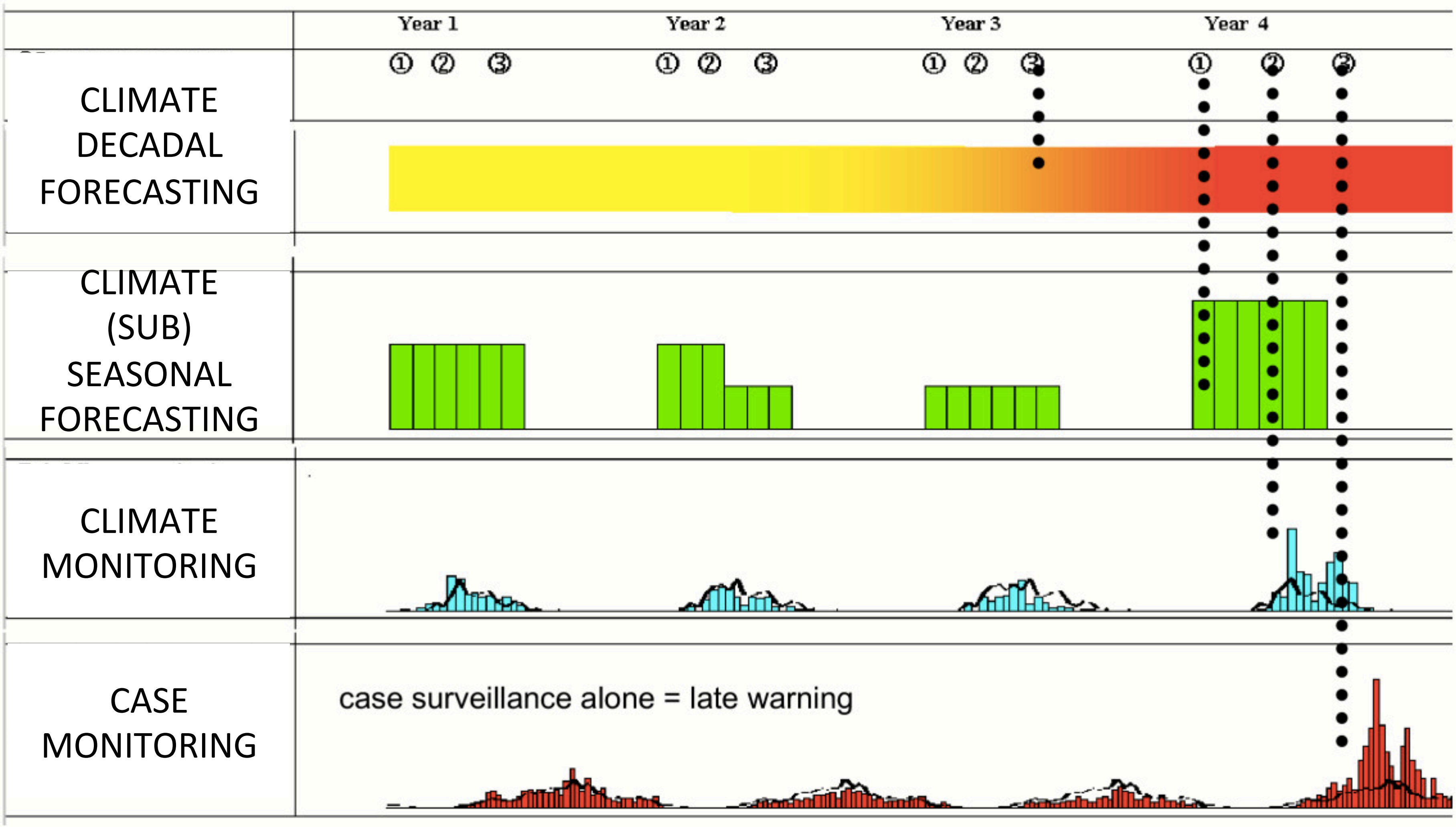
Example from village in SW Niger from Bomblies et al. (2008)



Blue - Rainfall
Dots - Malaria cases in 3 seasons

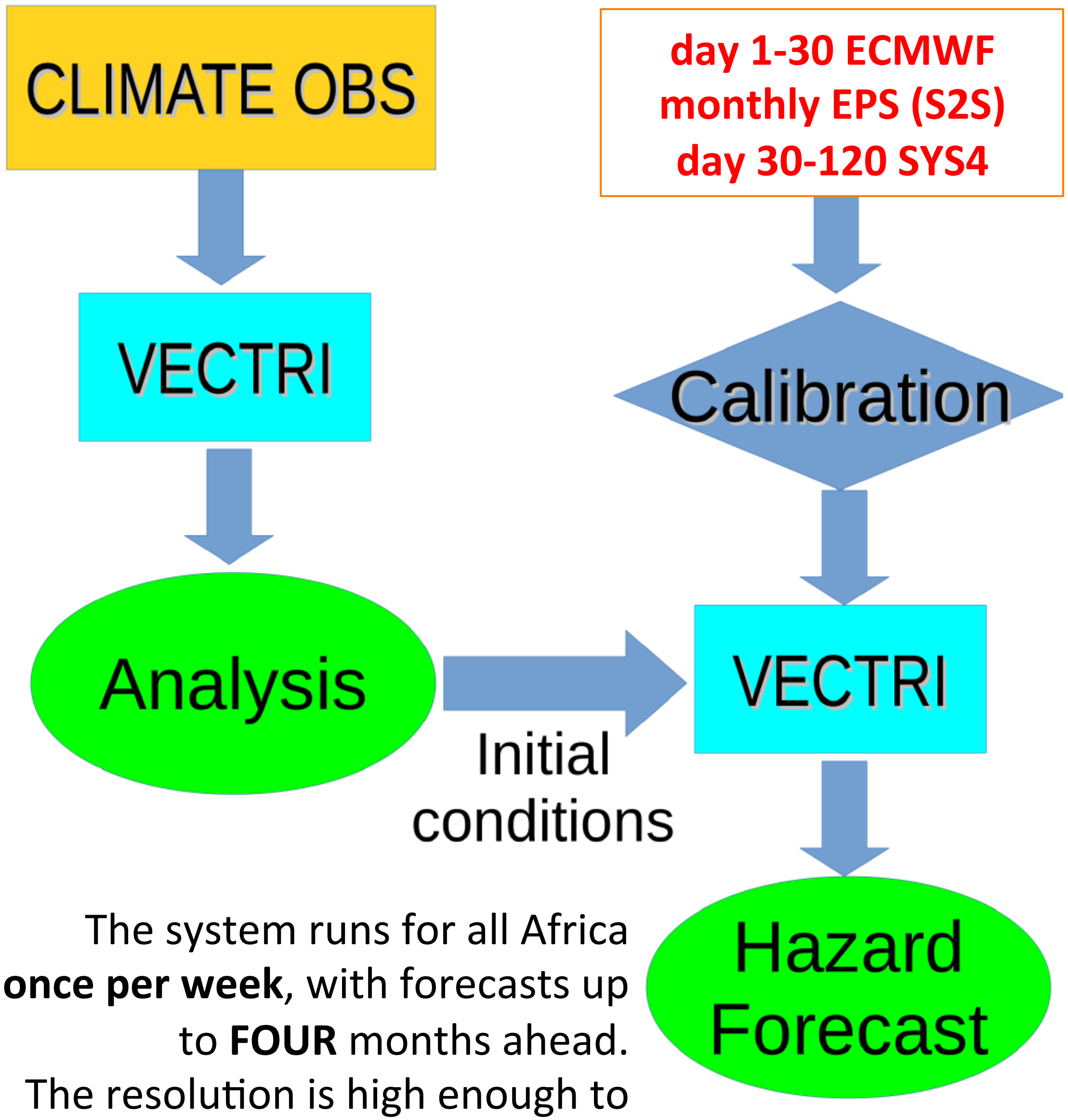
Rainfall monitoring can give 1 to 2 month early warning – S2S would aim to EXTEND this by 1 to 2 months

Climate prediction used to extend early warning "lead time"



Adapted from DaSilva et al. 2004, Malaria Journal

Climate observations are used to create an analysis of entomological and epidemiological conditions in order to initialize the malaria forecasts using the ICTP dynamical malaria model VECTRI (Tompkins and Ermert, 2013).



The system runs for all Africa **once per week**, with forecasts up to **FOUR** months ahead. The resolution is high enough to **resolve health districts**

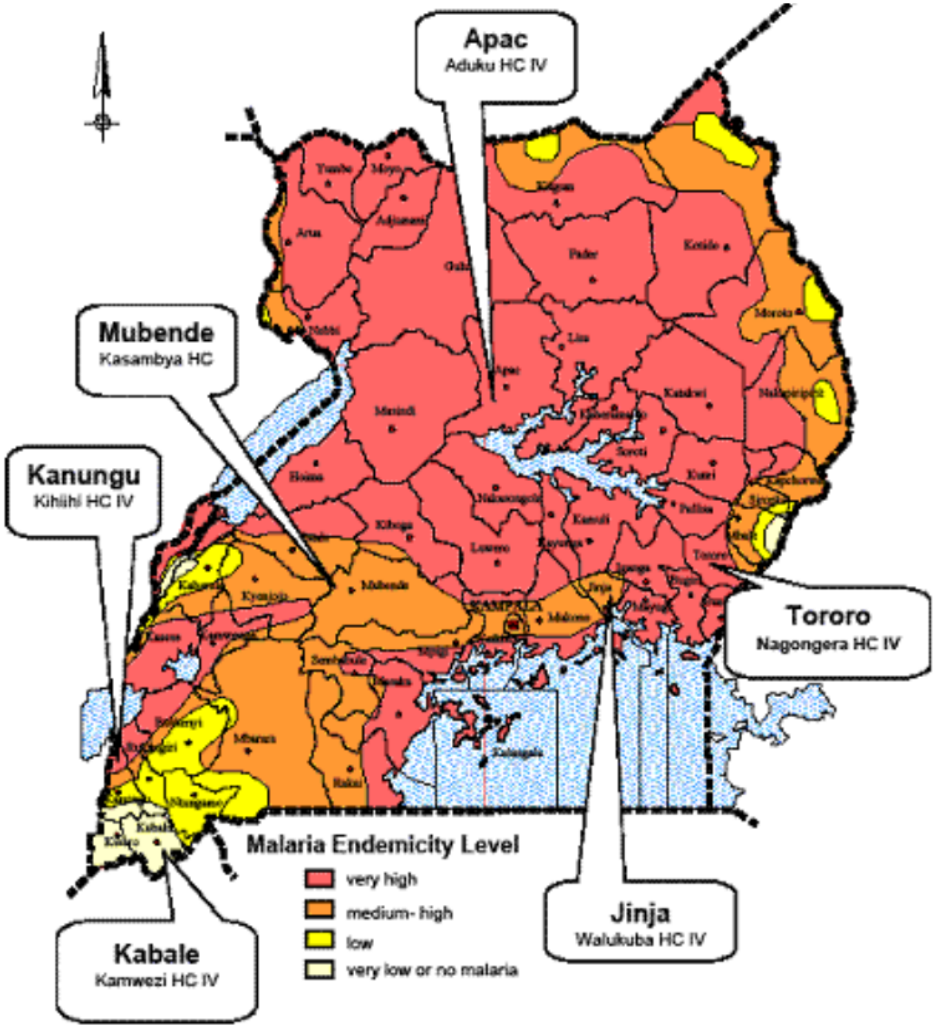
Uganda analysis

We present a preliminary evaluation of the normalized logarithm of the entomological inoculation rate, ln(EIR), from

- Malaria Analysis system
- Malaria Forecast system from 1 to 4 months ahead

Comparing to observed malaria cases.

- MoH district data suspected cases 2002-2010
- UMSP confirmed cases from 6 sentinel sites 2006/09-2013



Results for Jinja Sentinel Site

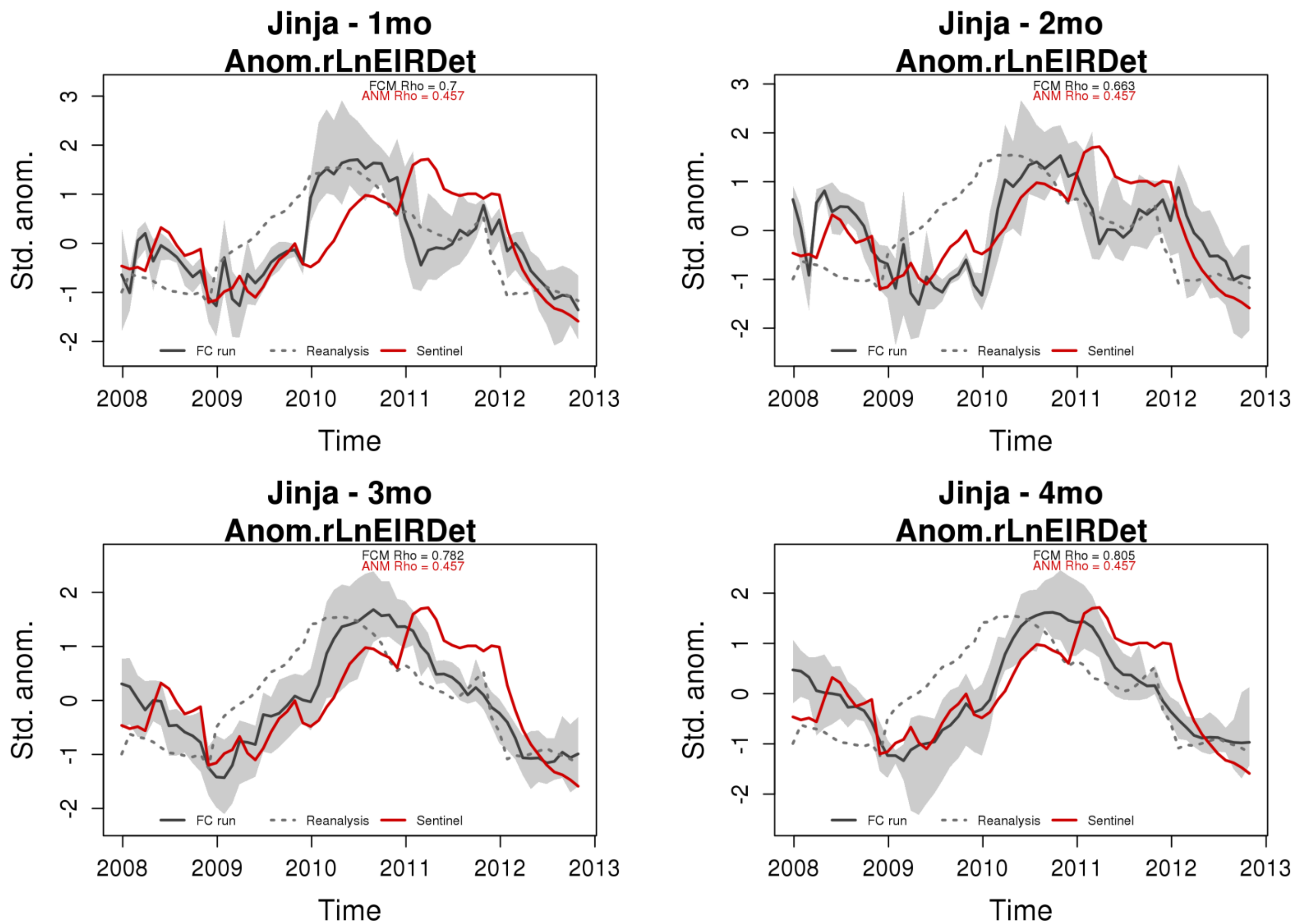
Red line: normalized **confirmed** cases

Black Line: normalized malaria forecast (ln(EIR) – no immunity in model yet)

Grey shading: **range** of the 5 forecasts

Dash lined: the malaria initial conditions

Four panels: the four levels of advance warning



Results for Kanungu Sentinel Site

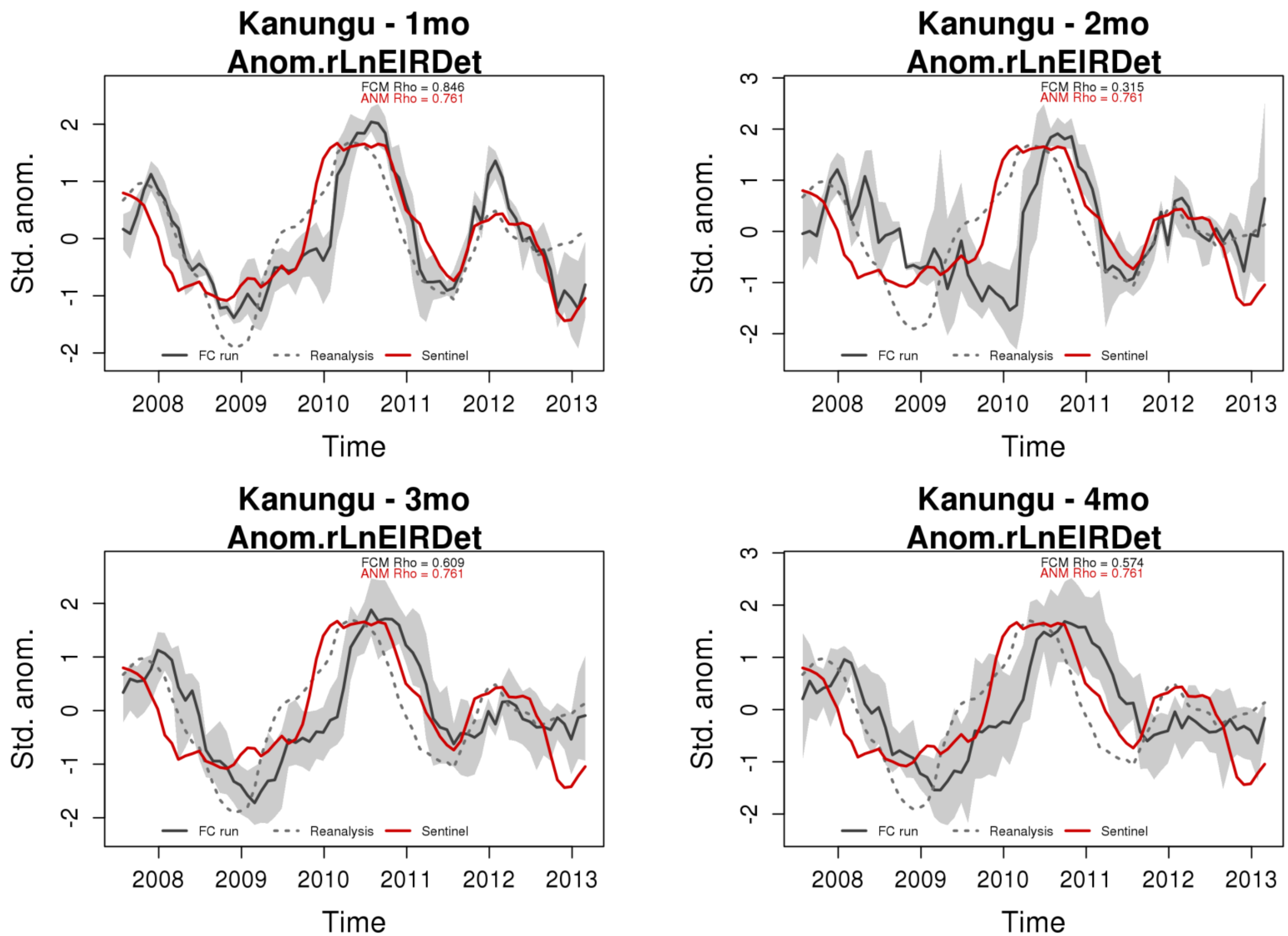
Red line: normalized **confirmed** cases

Black Line: normalized malaria forecast

Grey shading: range of the 5 forecasts

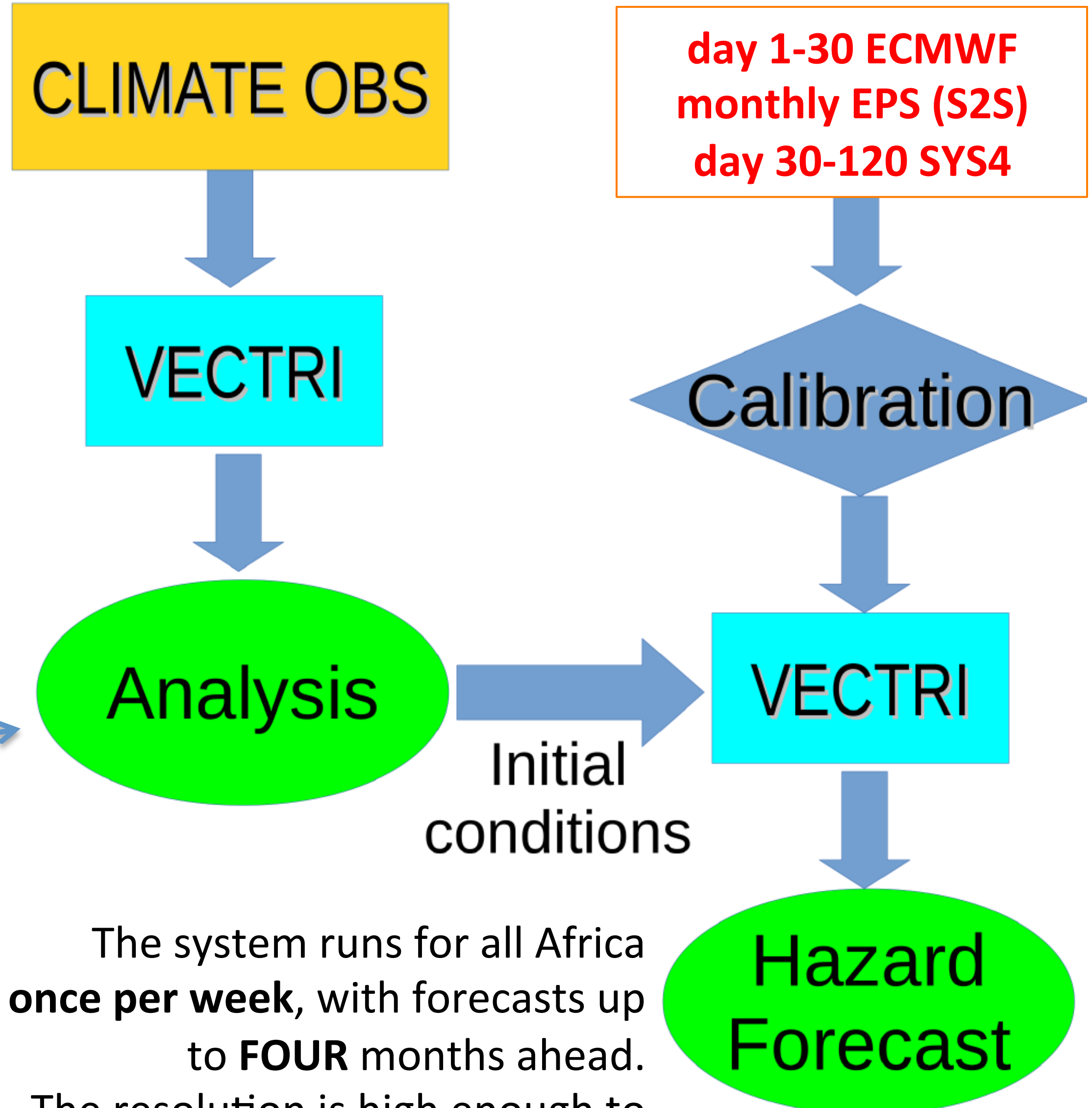
Dash lined: the malaria initial conditions

Four panels: the four levels of advance warning



Need to improve analysis for initial conditions

1. Cases
2. Vector densities
3. Pond coverage
4. Larvae densities
5. Biting rates
6. Infectious biting rates



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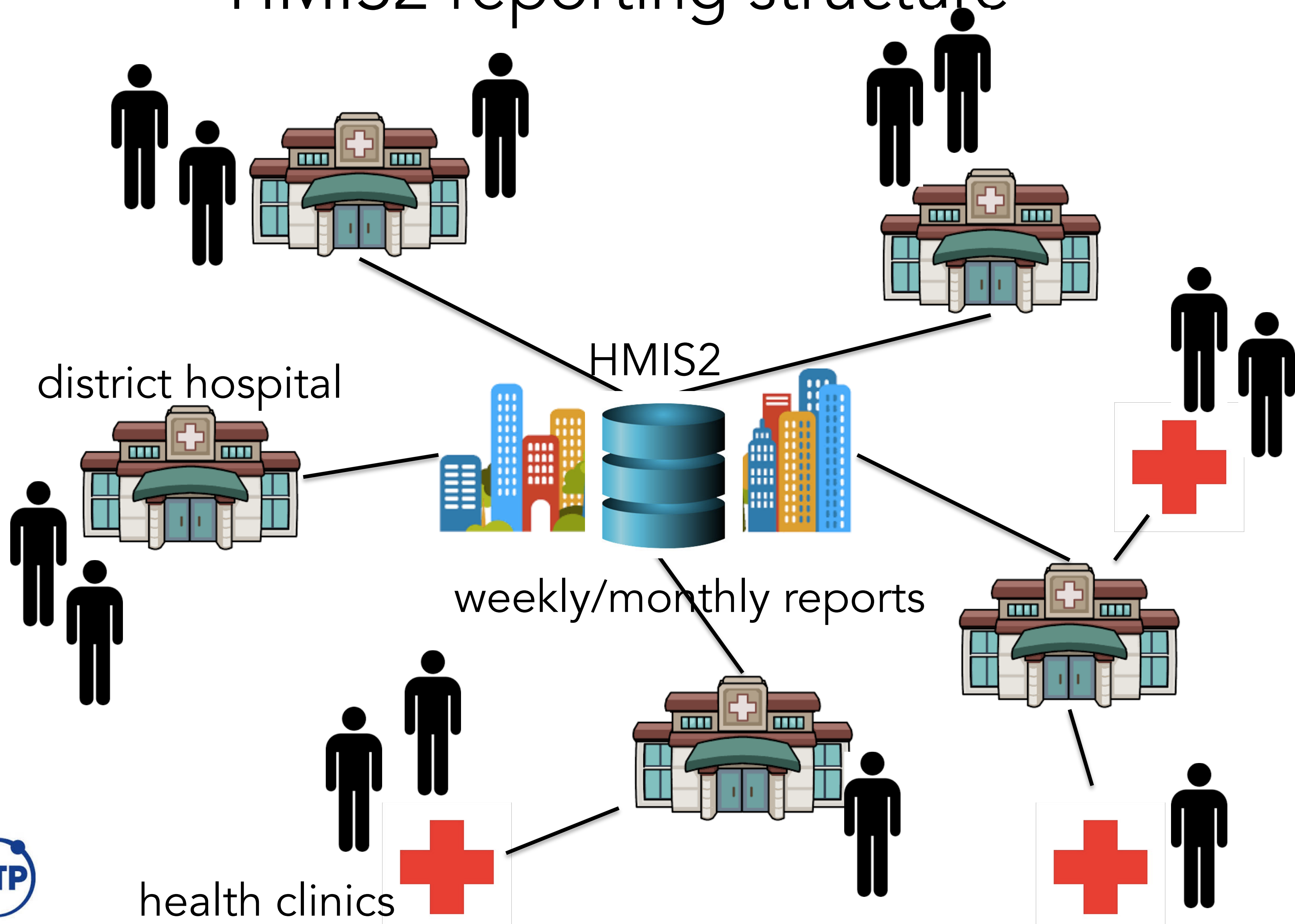
HMIS2 reporting structure



Monitoring of vector state

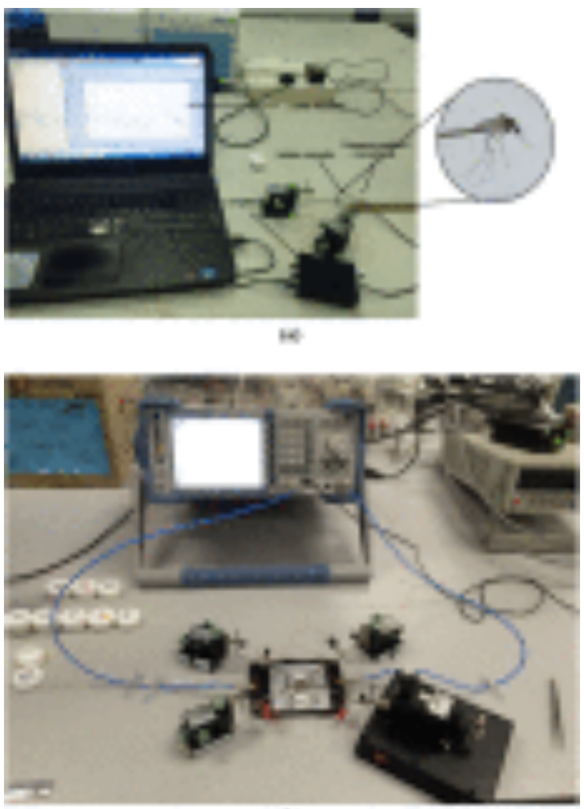
- Biting rates/EIR
  - CO_2 traps expensive to run
  - Human landing catches, difficult to organise and also permit
  - PCR techniques to calculate EIR expensive
- Pond fraction (availability of breeding sites)
  - Temporary ponds, metre scale
  - Attempts to use soil moisture or vegetation indices as proxies
- Larvae biomass
  - In situ measurements – labour intensive.

Role for acoustic monitoring and traps?

The Sounds of Disease-Carrying Mosquitoes

The Journal of the Acoustical Society of America **21**, 259 (1949); https://doi.org/10.1121/1.1906505

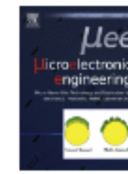
Wm. H. Offenhauser Jr. *and* Morton C. Kahn



ELSEVIER

Microelectronic Engineering

Volume 179, 5 July 2017, Pages 83-90



Research paper

Frequency-based detection of female *Aedes* mosquito using surface acoustic wave technology: Early prevention of dengue fever

Zaid T. Salim [a], U. Hashim [a], M.K.Md. Arshad [a], Makram A. Fakhri [a, b], Evan T. Salim [c]

- ❑ Detection, and also outbreak prevention

Would enable high resolution mapping of risk to improve understanding of transmission patterns at small scales.

Fig. 1. **Relationship of malaria incidence and *Anopheles* mosquito numbers to distance from breeding sites of the *Anopheles* malaria vectors in urban or periurban locations in Africa and the Indian Ocean.** The data are re-expressed from published studies as indicated. The malaria index is the value of the parameter used to measure malaria incidence (e.g. spleen rate (*28*)) malaria seropositivity rate (*22*), parasite rate (*9*) expressed as a fraction of its maximum in relation to distance from a vector breeding site. The *Anopheles* index is the recorded density of *Anopheles* expressed as a fraction of the maximum densities recorded in relation to distance from the breeding site. *Anopheles* densities were measured by means of indoor insecticide spray collections from houses (*22*).

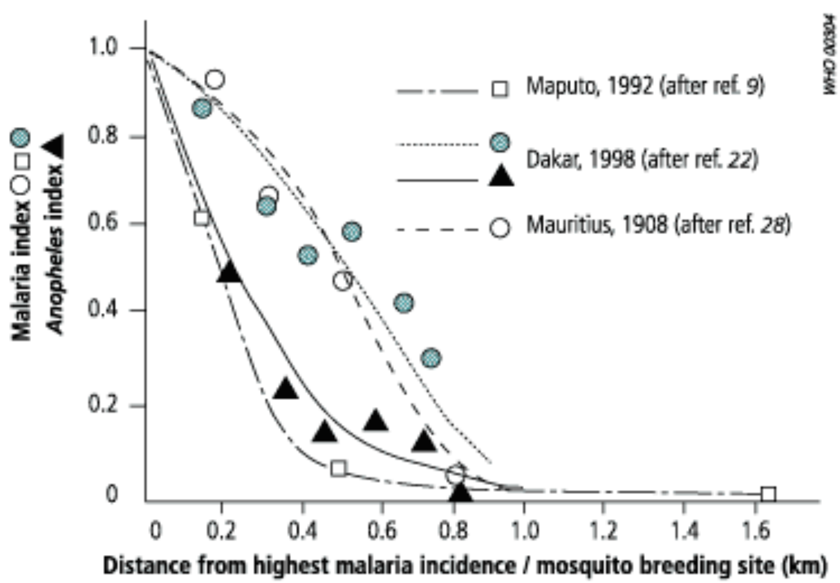
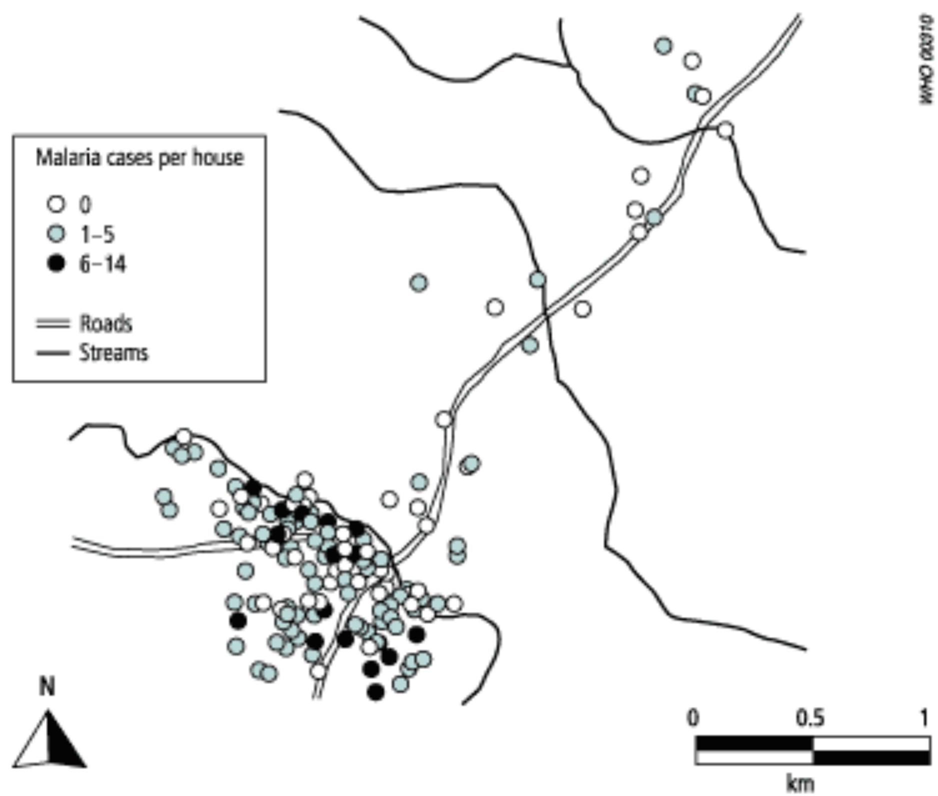
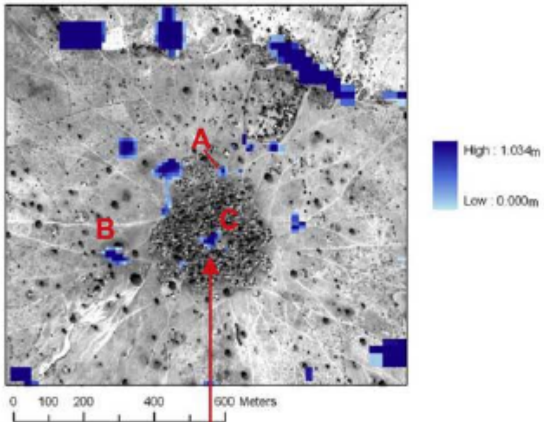


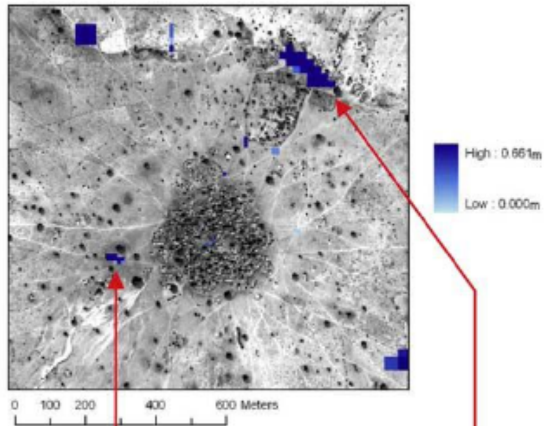
Fig. 7. **Clustering of malaria cases in 198 houses in the village of San Pedro, southern Belize.** From 1989 to 1996, 50% of malaria cases occurred in only 16,i.e. 8%, of houses (shown in black) (cf. Table 1, Fig. 8). Landsat data (not shown) on ground features of this area are also available (from *D.R.* on request) assisting the location of potential mosquito breeding sites. The map illustrates the potential for combining malaria, census and satellite data within a GIS profile of malaria risk at the neighbourhood down to the household level.



Example from Carter et al. Spatial targeting of interventions against malaria

Pond monitoring?





High resolution satellite sensors not good at detected metre scale ponds

Bomblies et al. 2008