Malaria Early Warning System for Uganda using ECMWF weather forecasts to drive a dynamical malaria model

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Background

Despite a global contraction in range over the past century, malaria still imposes a significant health and socioeconomic burden to many countries, mainly in Africa.

Key cycles of the malaria system are influenced by temperature and rainfall. Monthly and seasonal dynamical climate prediction systems have significantly improved their skill in the tropics over recent years, there is potential to use such forecasts to drive dynamical malaria models to provide early warnings of climate-related transmission hazard, particularly in epidemic transmission settings.

Malaria forecasting could provide important information for developing bespoke interventions, and for the efficient alloction of resources.

Here, we introduce a pilot dynamical malaria prediction system interfacing a dynamical malaria model with an operational state-of-the-art weather forecast system.

Methods

Temperature and precipitation forecasts from the European Centre for Medium-Range Weather Forecasts (ECMWF) monthly and seasonal ensemble prediction systems were used to drive dynamical malaria model VECTRI[1] to produce forecasts of malaria metrics **up to four months ahead.** The hindcast ensemble consists of 5 members (increased to 15 in the lastest update).

The system predicts parasite ratio (PR), Entomological Inoculation rate (EIR), and in the most recent version, clinical cases per 1000 population*. Malaria forecasts were started from realistic initial conditions derived from climate monitoring.

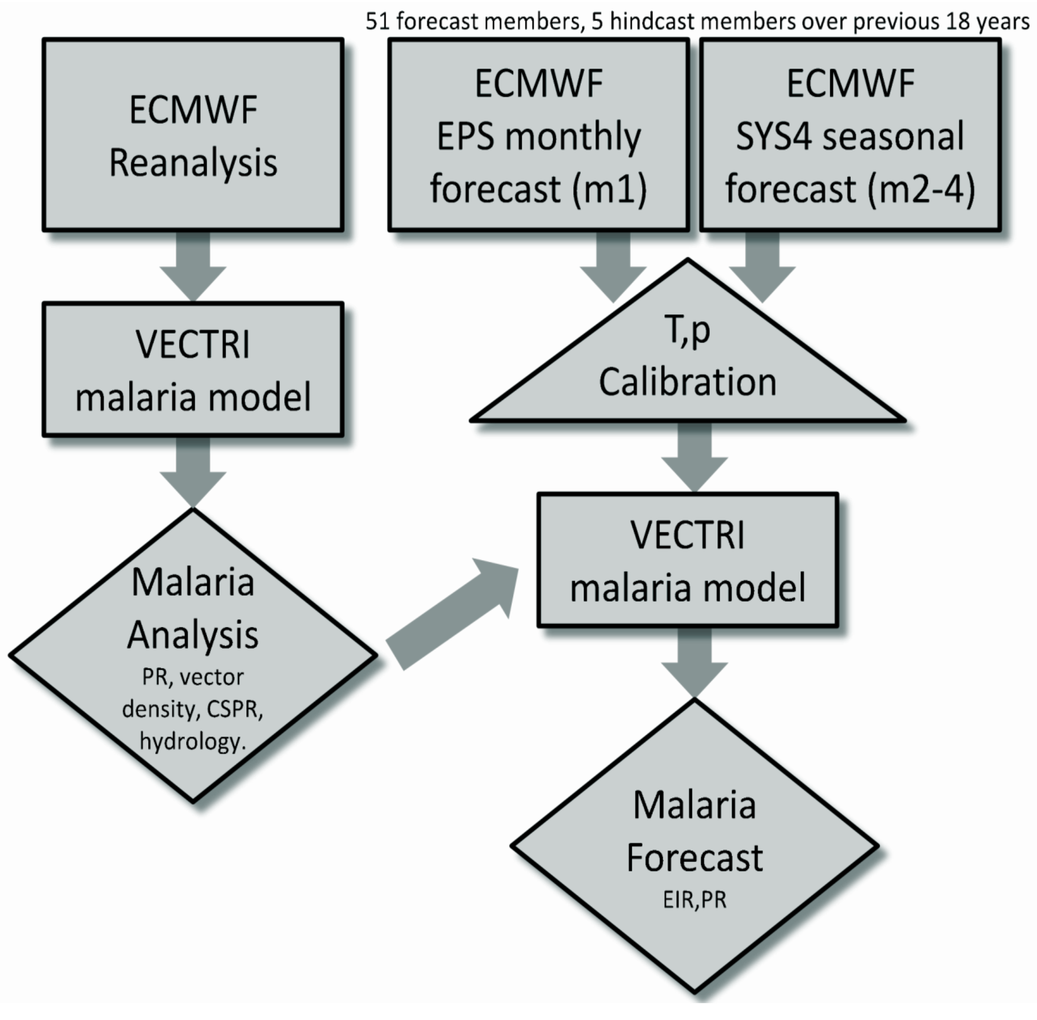
Forecasts were computed on a grid mesh with a spatial resolution of 25 km. Data were aggregated at the administrative district level. Sentinel site data is compared to the aggregated district forecast for the district in which the site is located.

Malaria predictions were evaluated against normalized district level suspected cases (approximately 9 years) or laboratory confirmed sentinel site cases (4 to 6 years) for Uganda

Spearman rank correlations were computed to determine the relationship between the (log) EIR surveillance data. Data were detrended to reduce the impact of possible long-term trends on the computation of correlation coefficients.

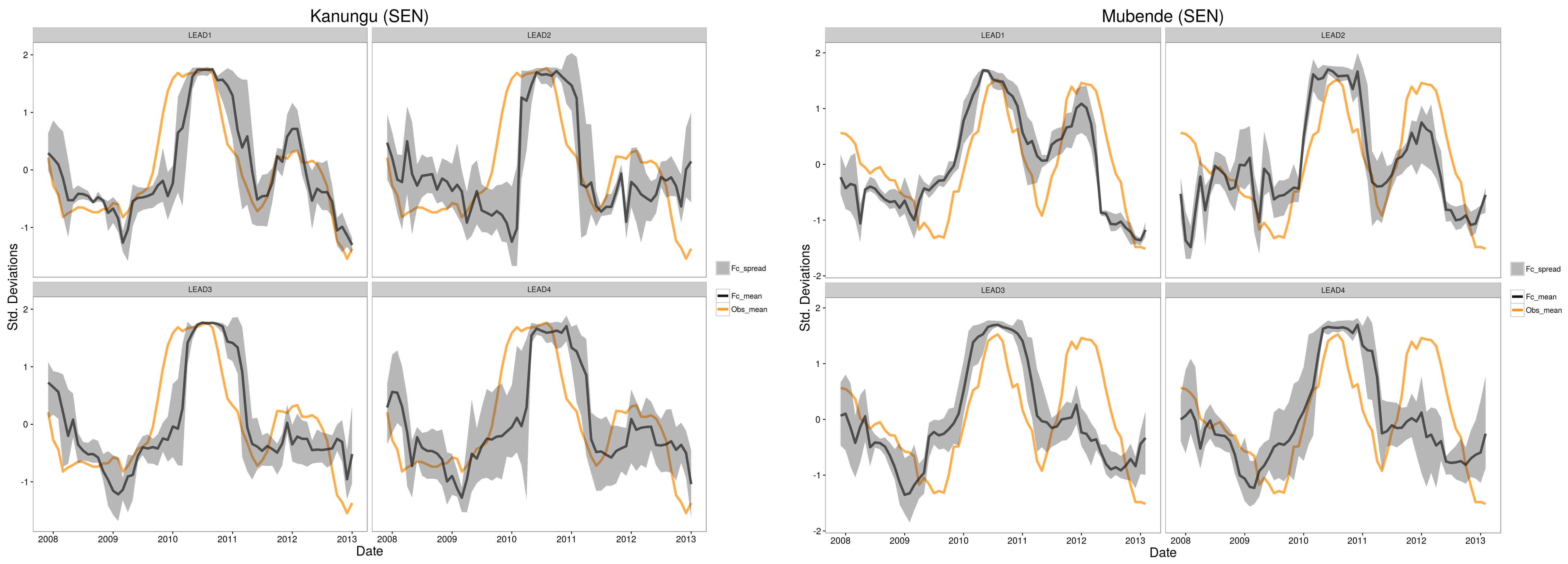
The figure depicts a schematic representation of the seasonal malaria forecasting system. Boxes represent models, triangles are processes, and diamonds are products.

*The results shown here are from the previous model version for which clinical cases was not available, hence we use a function of EIR related to the logarithm to compare to case data

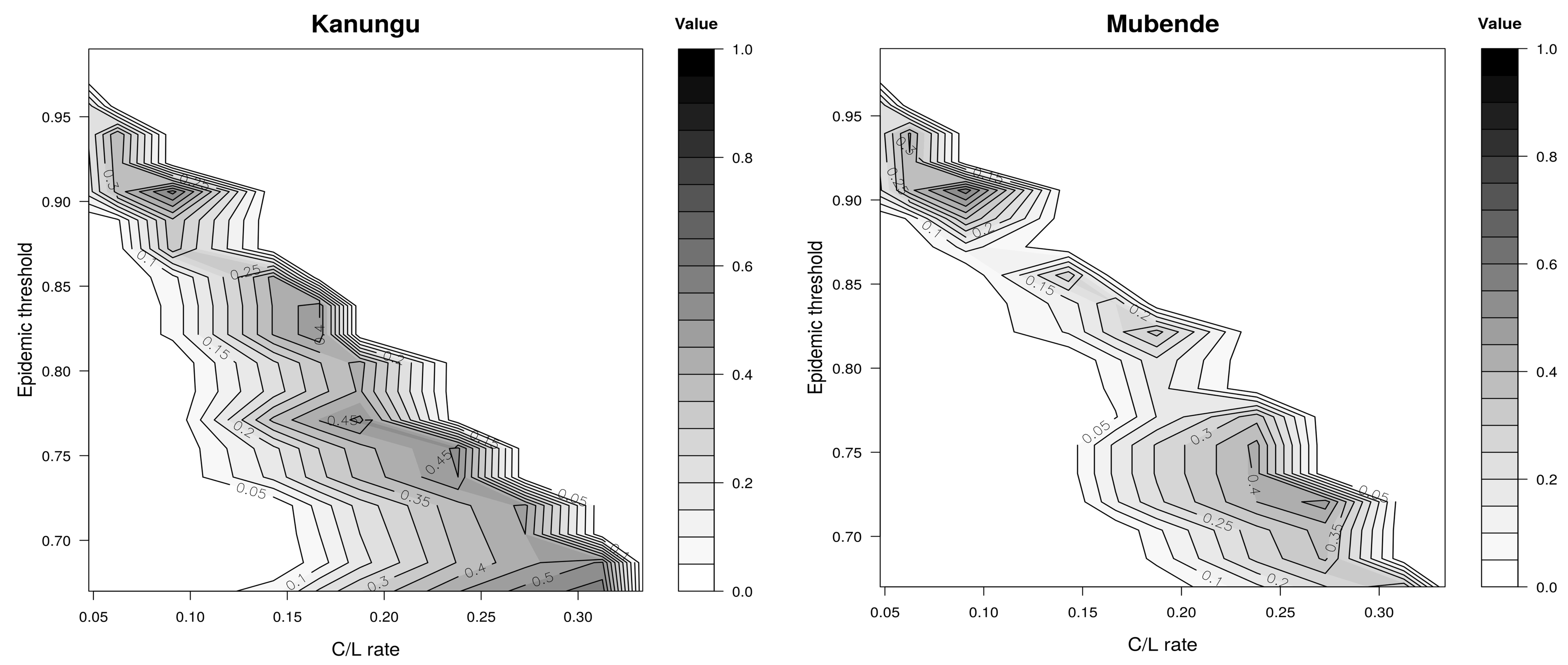


Above: Schematic of version 1 of the pilot dynamical forecast system, described in Tompkins and Di Giuseppe 2015.

Evaluation against sentinel sites

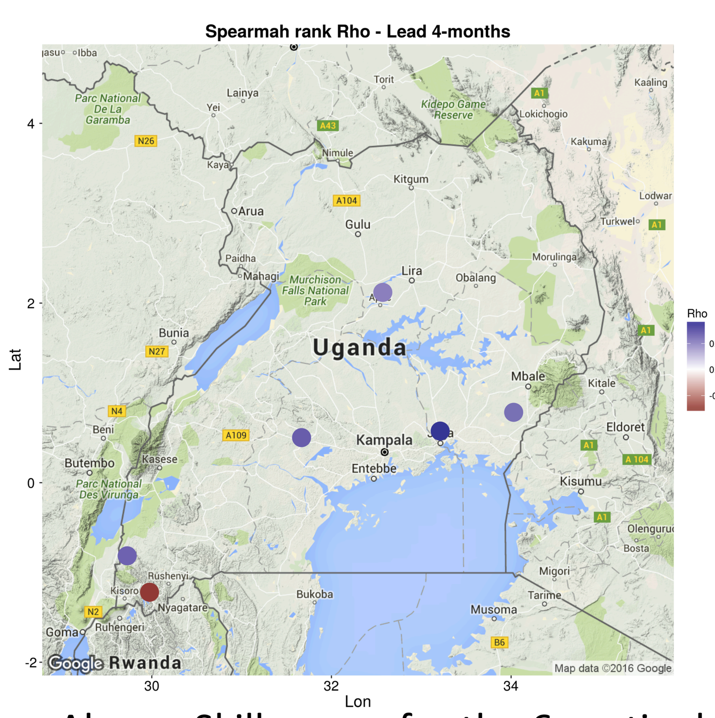


Above: Timeseries of forecast predictions at forecast lead times of 1,2,3 and 4 months in advance for the two focus sentinel sites of Mubende and Kanungu. The shading shows the uncertainty due to the climate predictions. A single deterministic and uncalibrated version of VECTRI is used.

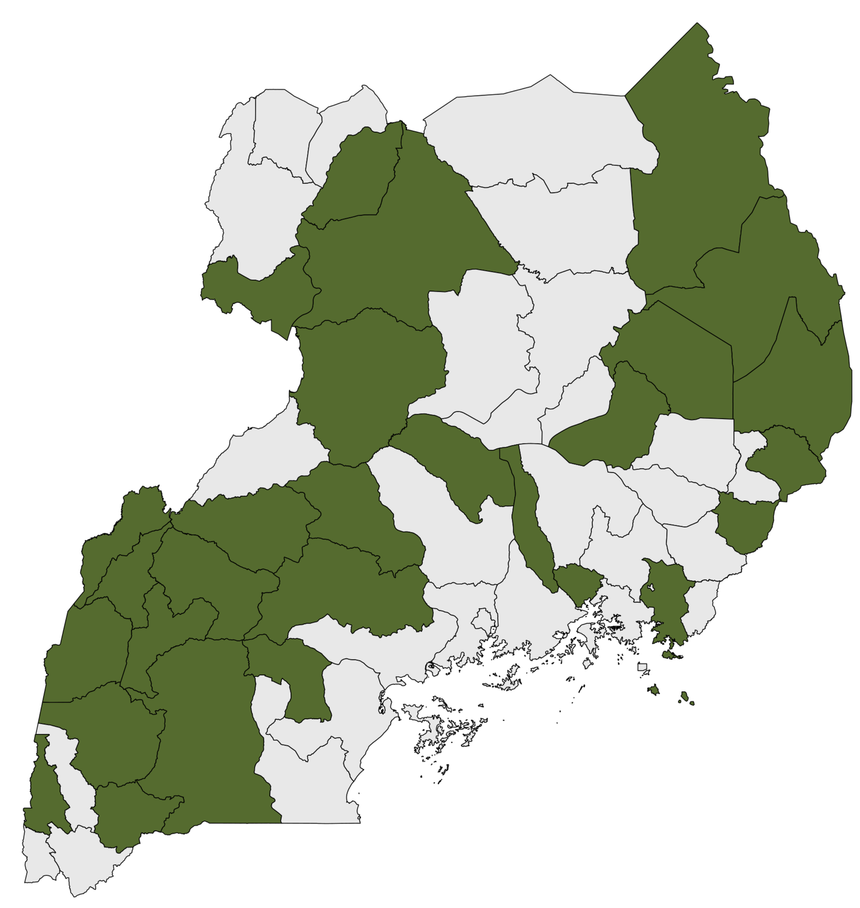


Above: A simple economic analysis of the forecast models at two sentinel sites. On the Y-Axis, a threshold is chosen for a given transmission anomaly. For example, y=0.8 represents a 1 in 5 anomalous **month**, consistent (*but not identical**) to the threshold recommended by the WHO to define an epidemic. A 2x2 contingency table is constructed. If the event is predicted, an intervention is carried out at cost C. If the event occurs but no preventative action was taken, a loss L occurs. The shaded area shows at which cost-loss (C/L) ratios the system has economic benefit for each event threshold. At low cost-loss ratios, it is usually better to always intervene, at high cost-loss ratios, the system has to be very accurate to compensate for the expensive forecast "false-alarms".

*The WHO definition is based on a *lagged* running window of 5 years and works on seasonal anomalies. Due to the short health data series, we use the entire series and work on monthly anomalies which also represents a much tougher test of the forecast system.



Above: Skill scores for the 6 sentinel sites in Uganda at a lead time of 4 months. The model does not simulate malaria transmission in Kabale, which is too cold. Calibration of the climate parameters (see poster 2) will likely improve performance > 2000m



Evaluation against epidemiological surveillance data

Left: The figure shows the districts that are skilful at the 4 month lead time using the longer but less accurate dataset of district suspected cases – approximately half of the districts show skill.

Conclusions

- Dynamical forecasting system shows promise evaluated against sentinel site and district health data on the sub-national scale
- Short data series a challenge for evaluation
- Calibration with genetic algorithm planned to improve performance and account for model process uncertainty (see other poster by Tompkins et al)
- Test integration into planning policy during a pilot "shadow" phase the next planned step in which the system is evaluated "post-season" to ascertain if the forecasts would have had value.

Further Reading

A. M. Tompkins, Ermert V. 2013. A regional-scale, high resolution dynamical malaria model that accounts for population density, climate and surface hydrology. *Malar J.* 12:65

A. M. Tompkins, F. Di Giuseppe, F. J. Coloń-González, and D. B. Namanya. A planned operational malaria early warning system for Uganda provides useful district-scale predictions up to 4 months ahead. In J.Shumake-Guillemot and L.Fernandez-Montoya, editors, *Climate services for health: Case studies of enhancing decision support for climate risk management and adaptation.*

A.. M. Tompkins and F. Di Giuseppe. Potential predictability of malaria using ECMWF monthly and seasonal climate forecasts in Africa. *J. Appl. Meteor. Clim*, 54:521-540, 2015.

Acknowledgements

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The VECTRI model is an open source code developed at ICTP freely available for research and educational use – see www.ictp.it/~tompkins/vectri