VECTRI - A high resolution regional malaria transmission model and its use in a pilot seasonal forecast system at ECMWF

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Climate drivers of malaria

- Rainfall : provides breeding sites for larvae.
- Temperature: larvae growth, vector survival, egg development in vector, parasite development in vector.
- Relative Humidity : dessication of vector.
- Wind : Advection of vector, strong winds reduce CO_2 tracking.

>2 bites are required to pass on the disease:

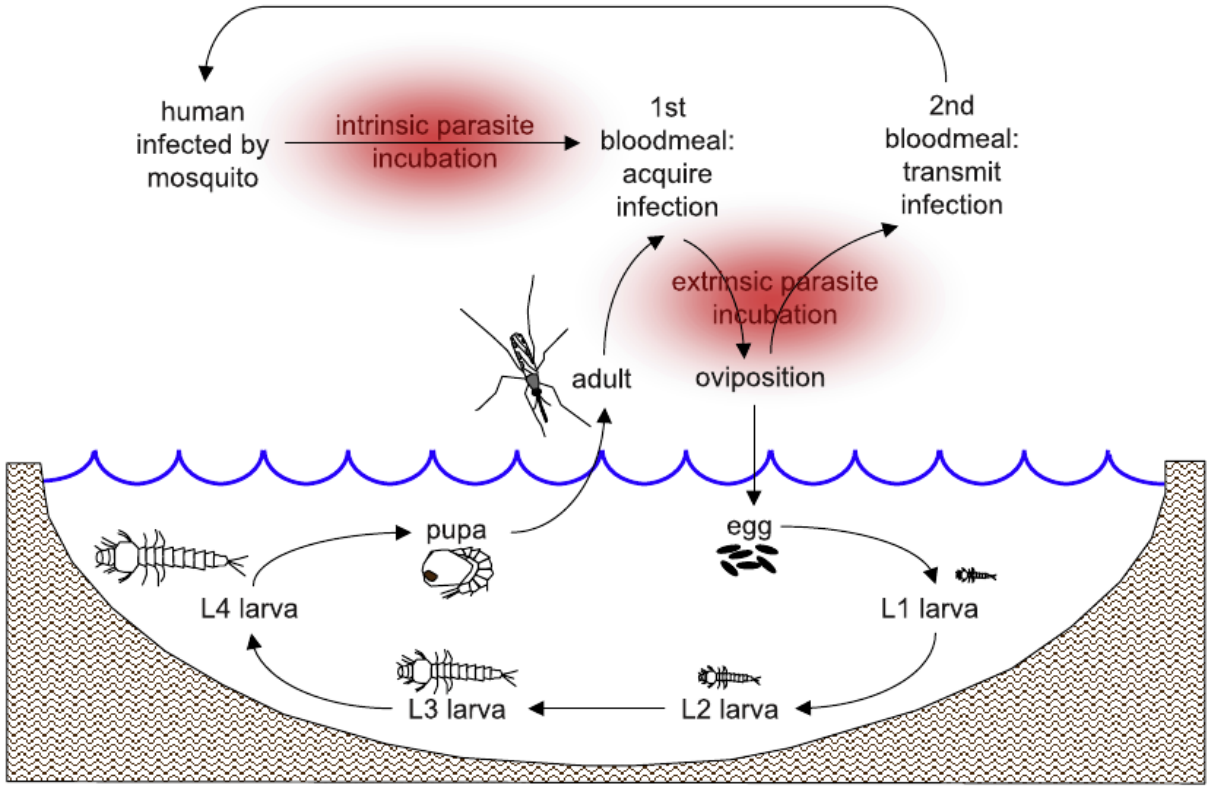


Figure: schematic of transmission cycle from Bomblies et al. 2008

VECTRI: VECtor-borne disease community model of ICTP, TRIeste

A model for the impact of weather on malaria, with:

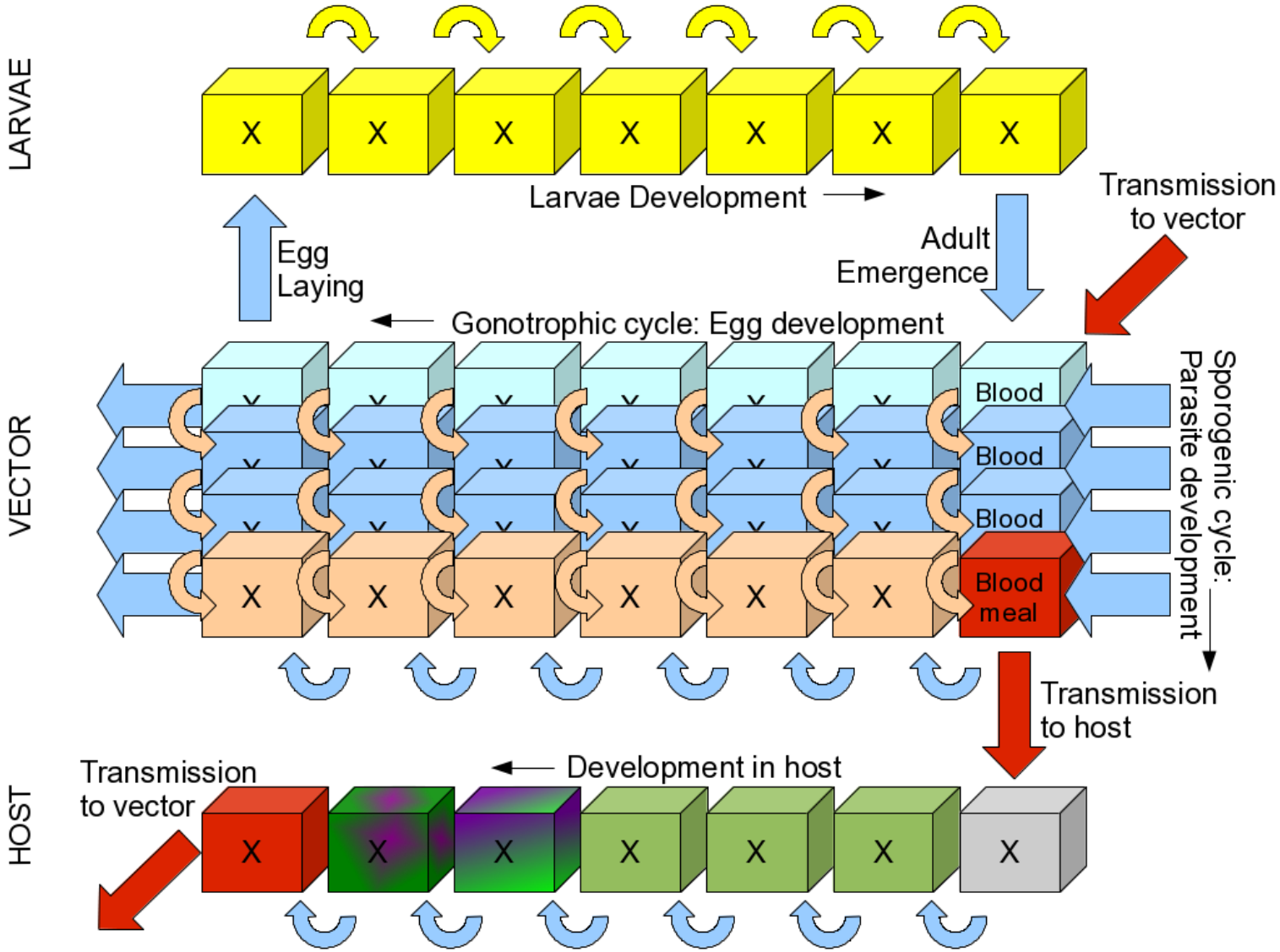
- daily timestep
- surface hydrology
- regional to global scales with resolution down to 5km
- incorporating population interactions (migration, immunity) and interventions (spraying, drugs, bednets).

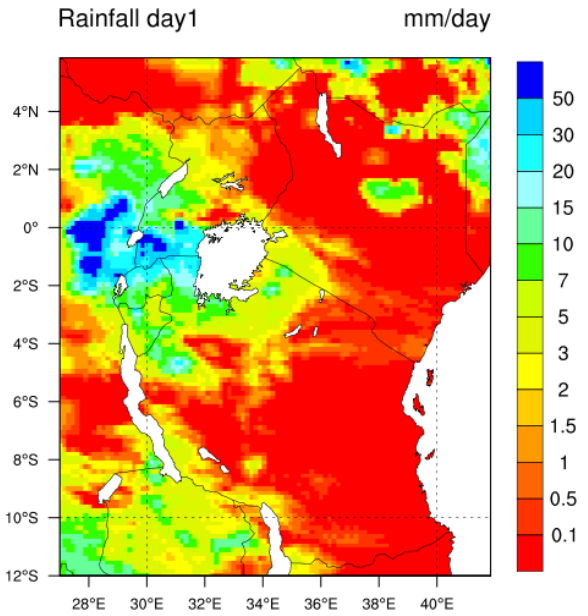
Uses:

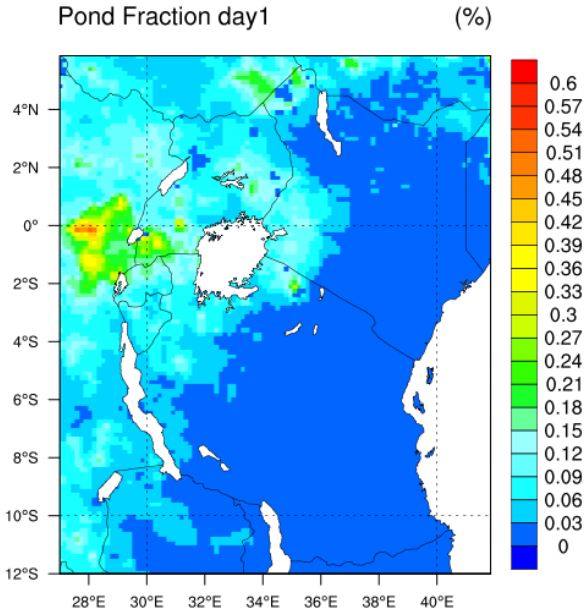
- Community model
- Research and operational tool
- Seasonal forecasting
- Climate projections

Further info:

http://www.ictp.it/~tompkins/vectri Tompkins A.M. and Ermert V, 2013: *A regional-scale, high resolution dynamical malaria model that accounts for population density, climate and surface hydrology*, Mal. J., **DOI: 10.1186/1475-2875-12-65**


LARVAE
Larvae Development
Transmission to vector
Adult Emergence
Egg Laying
Gonotrophic cycle: Egg development
VECTOR
Blood
Blood
Blood
Blood meal
Sporogenic cycle: Parasite development
Transmission to host
Development in host
Transmission to vector
HOST





Breeding sites are divided into a permanent breeding fractions plus a temporary 'pond' fraction $w = w_0 + w_{pond}$. A competition factor limits larvae biomass to 300 mg m^{-2}, while intense rainfall flushes out larvae.

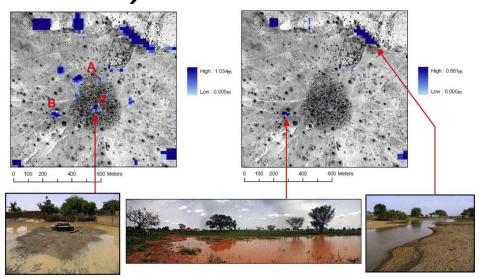
The rate of change of fractional pond coverage w_{pond} is given by

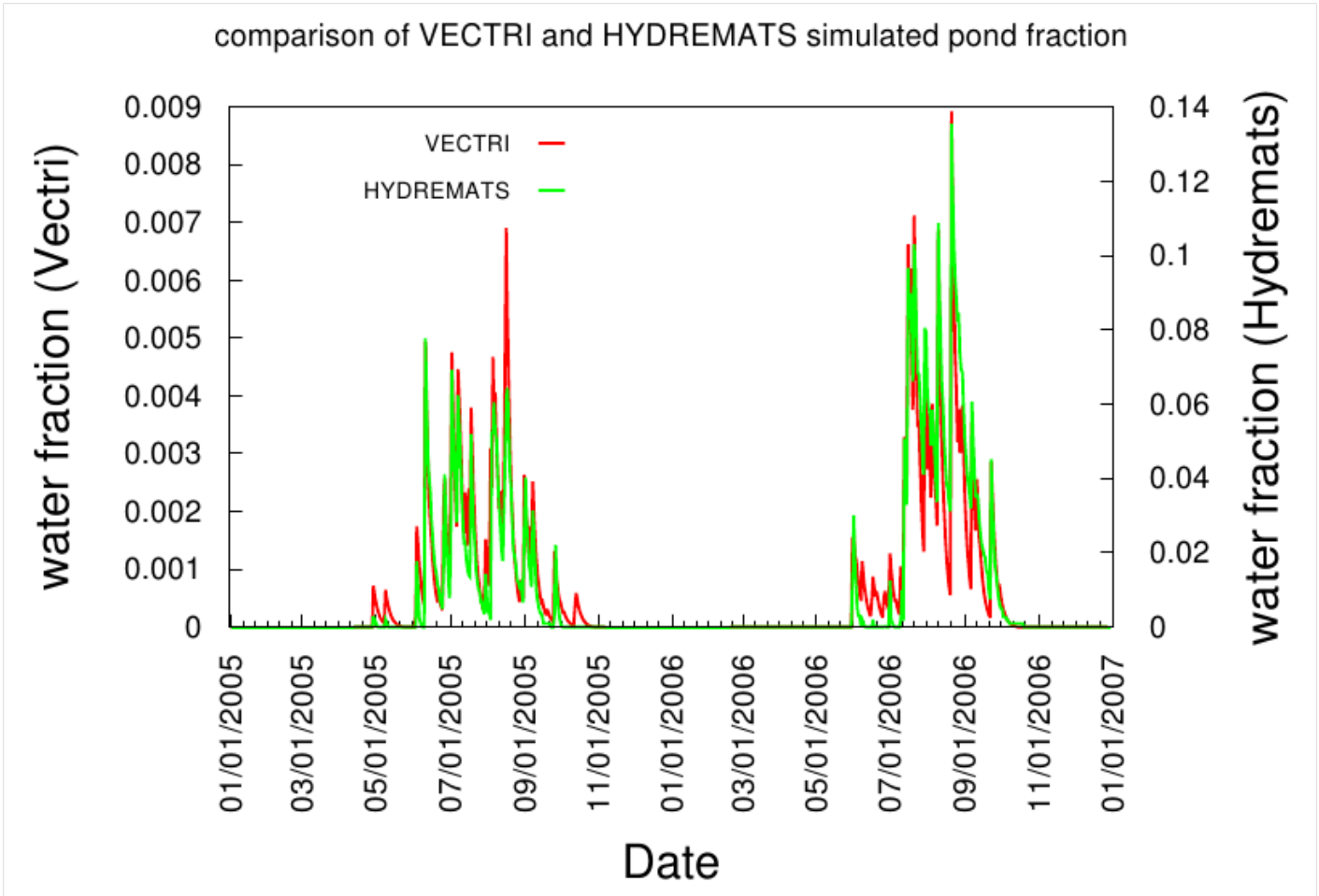
$$\frac{dw_{pond}}{dt} = K_w \left(P(w_{max} - w_{pond}) - w_{pond}(E + I) \right). \quad (1)$$

- P is the precipitation rate
- K_w is related to the aggregate pond geometry
- I Infiltration rate
- E Evaporation rate
- w_{max} Collection area = Maximum coverage (overflow losses)

VECTRI compared to 10m hydrology model

The two year integration of Hydremats at 10m resolution compared to VECTRI runs (Asare, Tompkins and Bomblies, 2013).





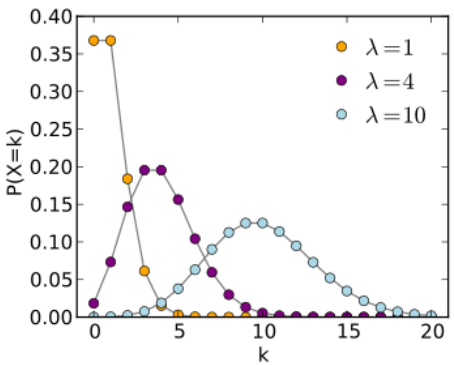
Use of TRMM similar, next step to evaluate with AMSR-E.

- Mean number of bites per human $B = V_b/D$ biting vectors density/population density
- Assume random distribution (all people equal)
- bednet (BN) use can be accounted for.
- single-bite malaria transmission probability is integrated over Poisson distribution to give transmission probability

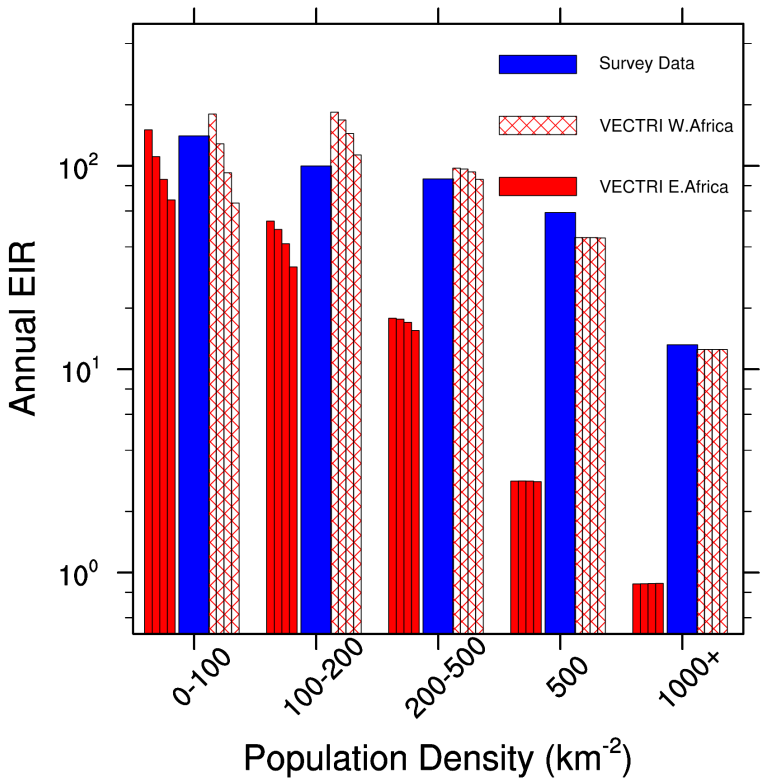
$$P_{vh} = (1 - P_{bednet}) \sum_{n=1}^{\infty} G_{B^*}(n) P_{v_i h}^n \qquad (2)$$

where G_B is the Poisson distribution for a mean bite rate B^*

Poisson distributions:



VECTRI EIR compared to survey data:

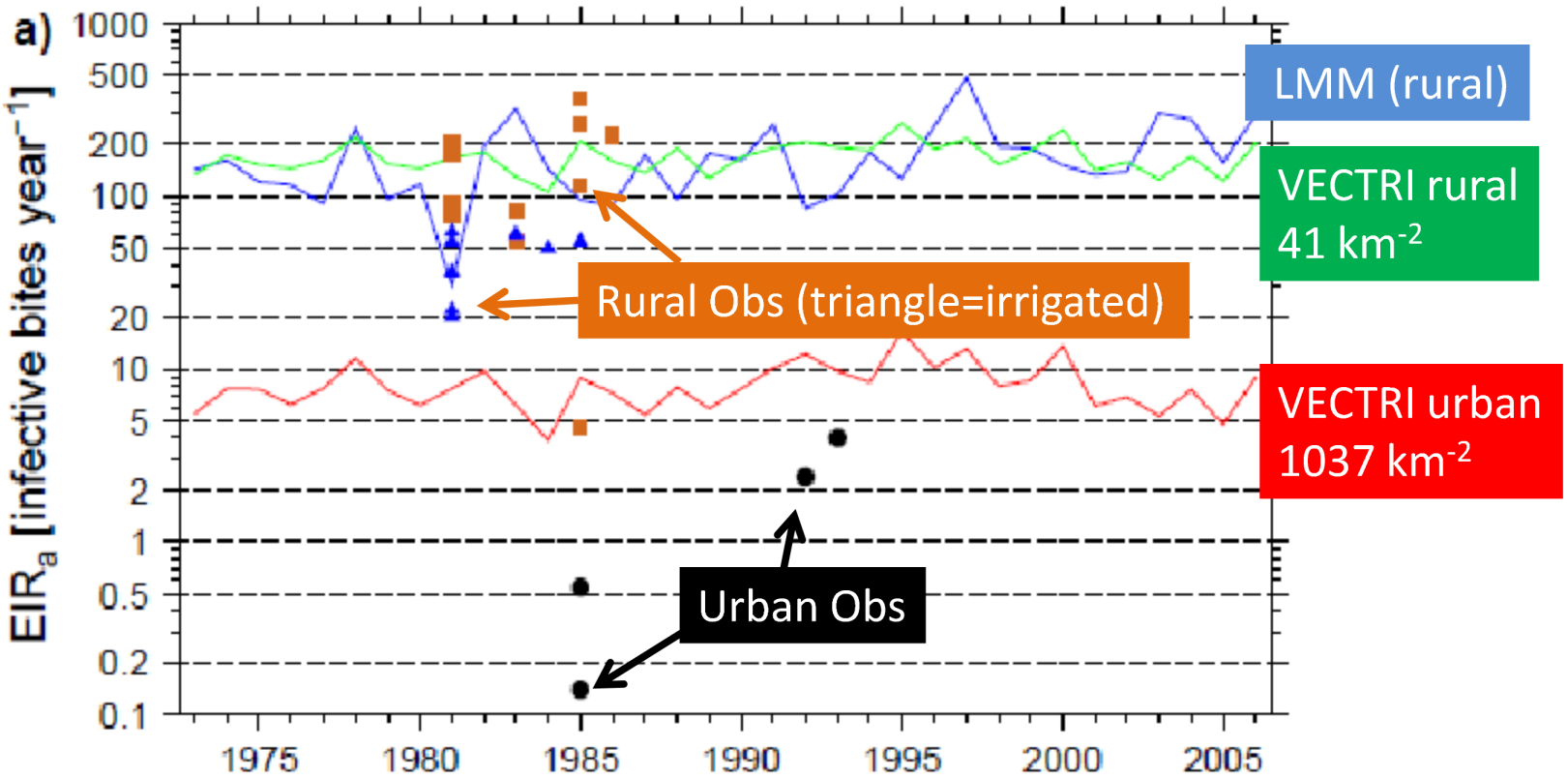


Long term runs with station data

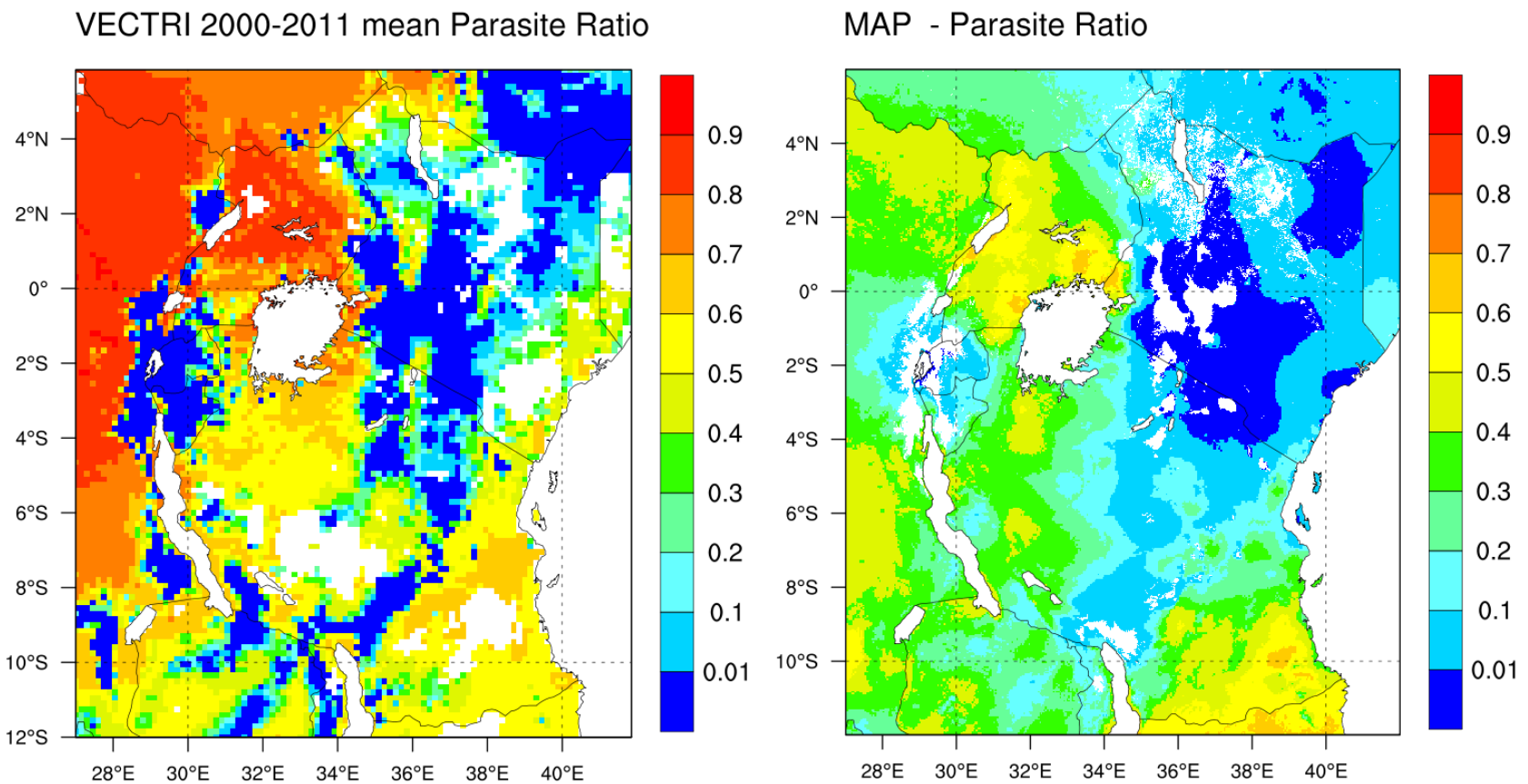
- An extensive literature search was conducted (Volker Ermert) to document studies measuring malaria parameters in Africa:
  - Malaria cases
  - Infected bite rates (EIR)
  - Ratio of infected to total vectors (CSPR)
- For each study location (many tens), if meteorological station data available nearby ($<$ tens of km) this was used to drive the vector models for multiple decades.
- The population density is remapped for a 5x5km cell around the *study site* (i.e. not the station).

QWeCI Science Talk

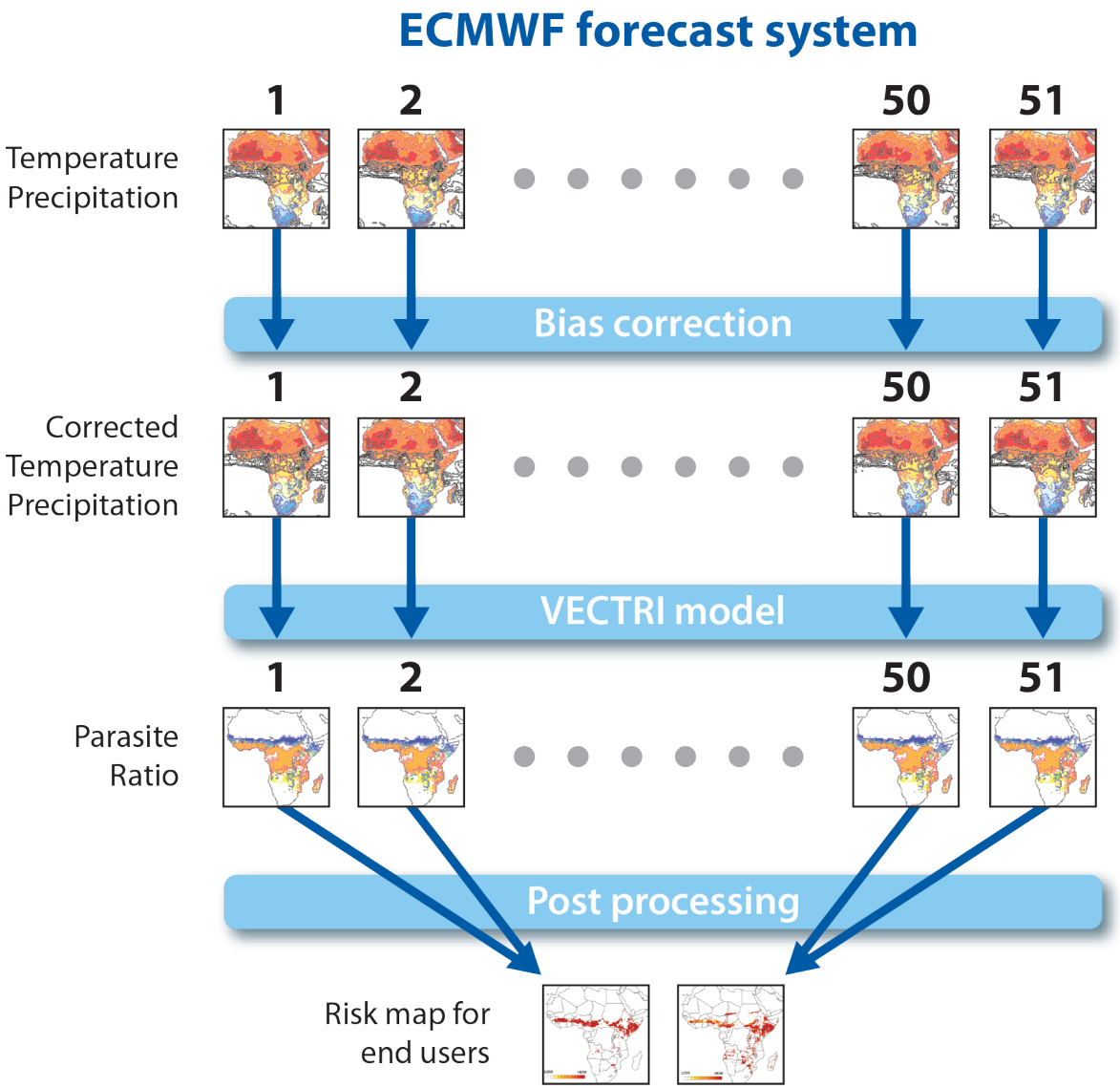
Bobo Dioulasso, Burkina Faso



VECTRI vs MAP Parasite Rates (PR)



MAP data from http://www.map.ox.ac.uk/



The ECMWF-ICTP dynamical Malaria Early Warning System

- Risk maps in terms of PR/EIR.
- hybrid system needed for case predictions
- see later talk for details

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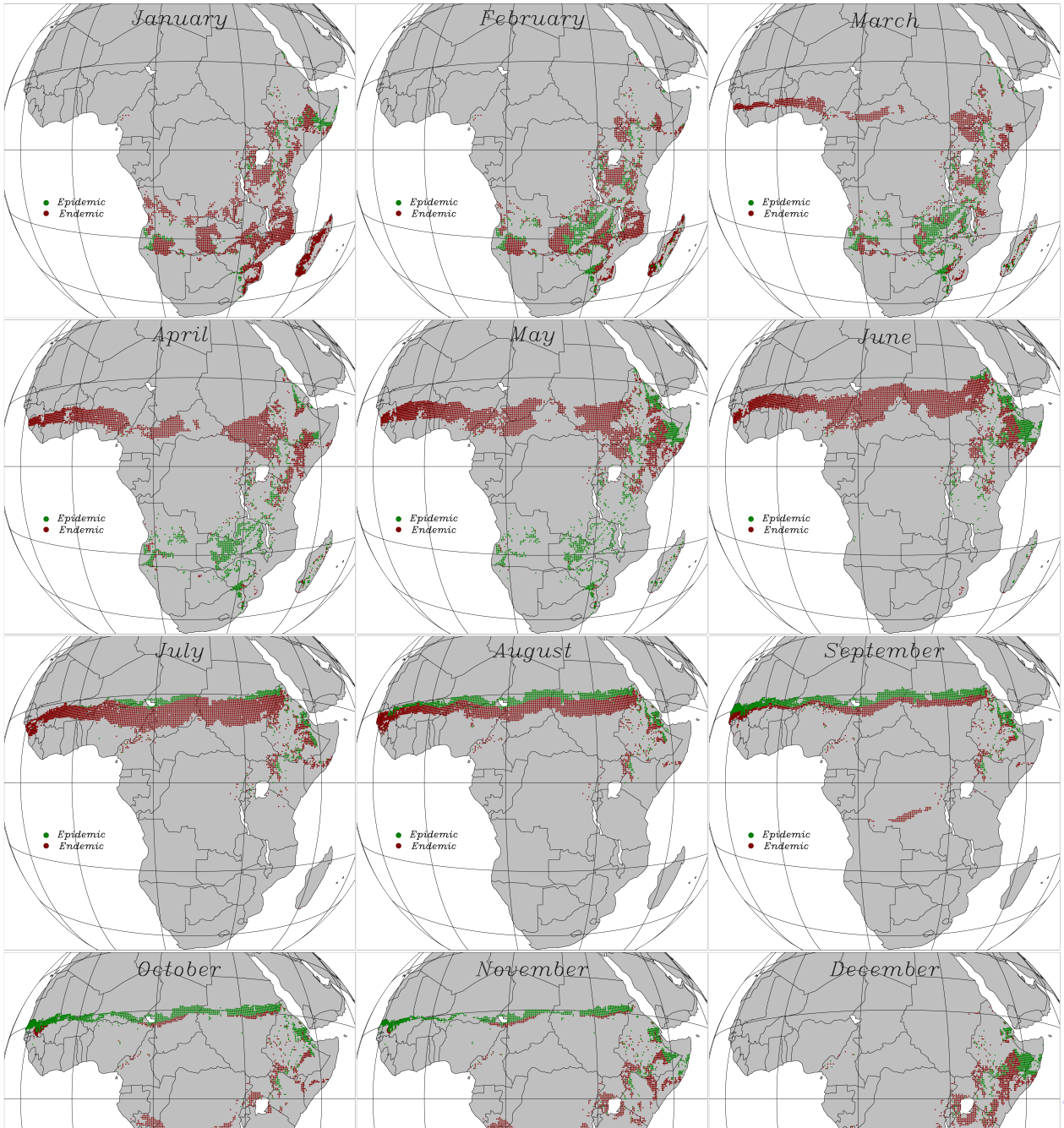
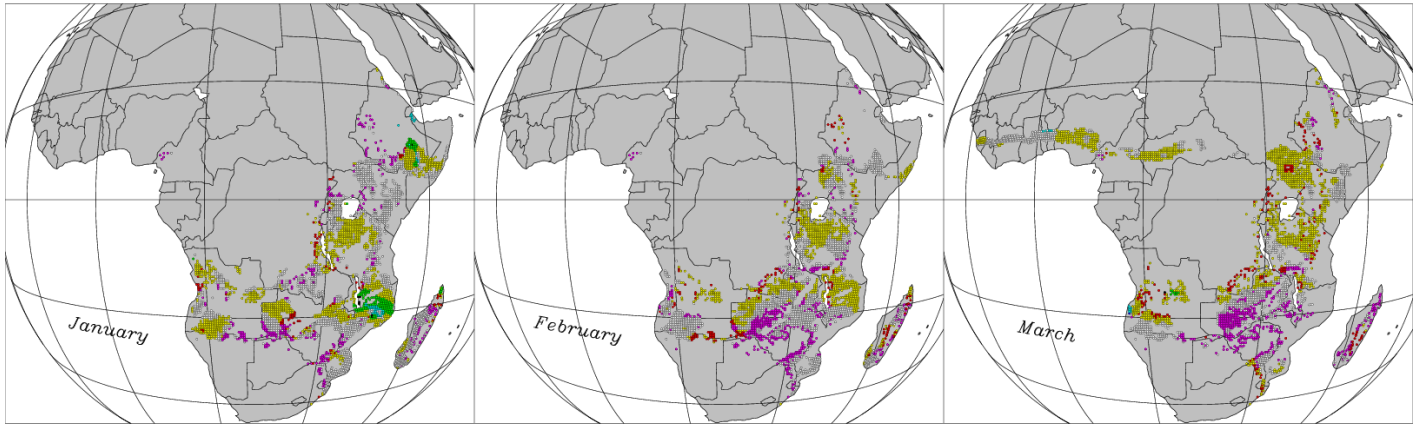
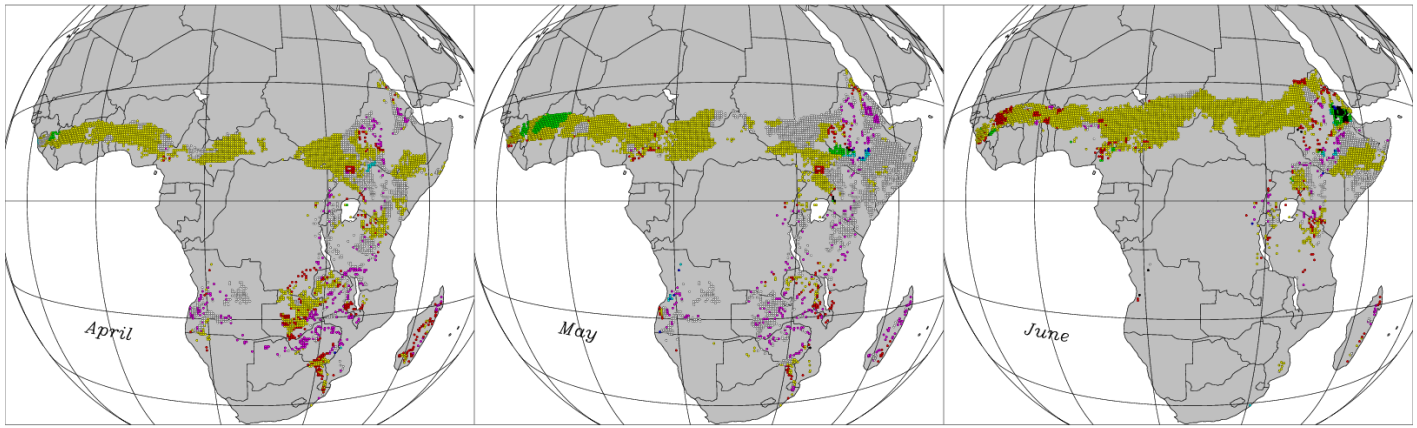
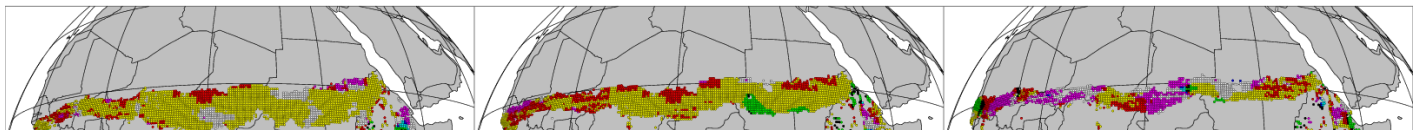
http://nwmstest.ecmwf.int/products/forecasts/d/inspect/catalog/research/qweci/

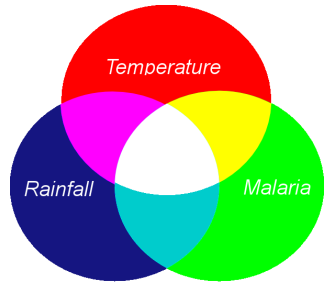

January
February
March
April
May
June
July
August
September
October
November
December
Epidemic
Endemic

Skill in predicting temperature, rainfall and malaria PR at month 1 lead in areas of high variation. Black=no skill. (Tompkins and Di Giuseppe, submitted).









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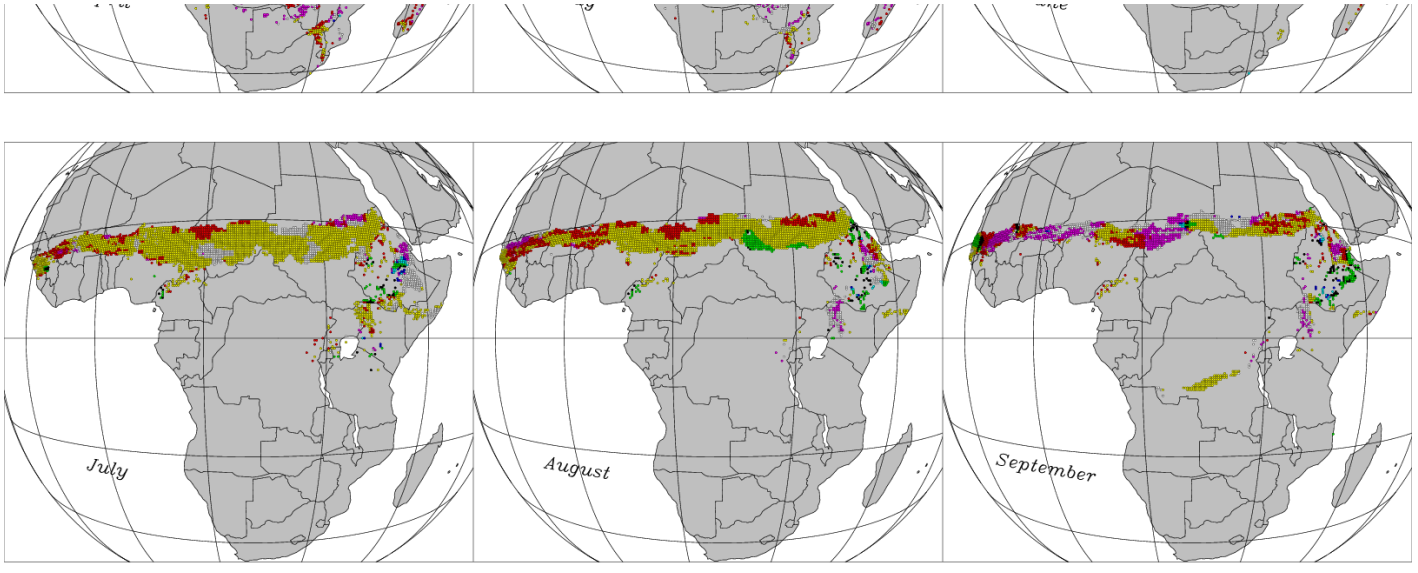
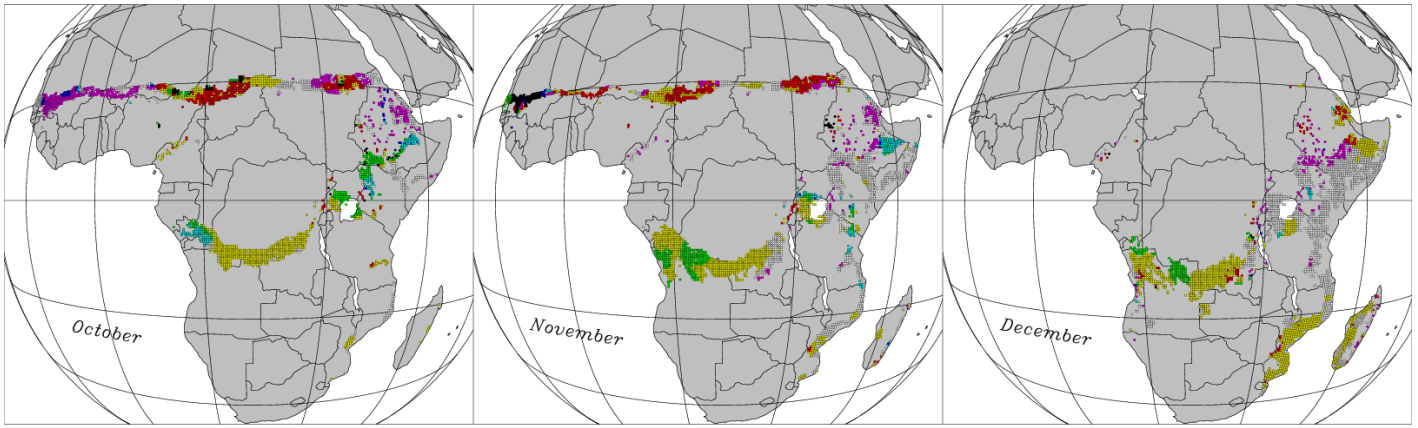
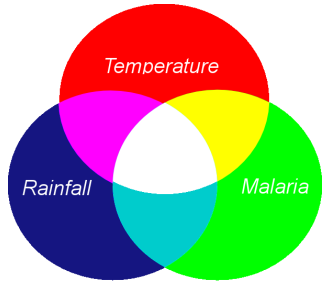
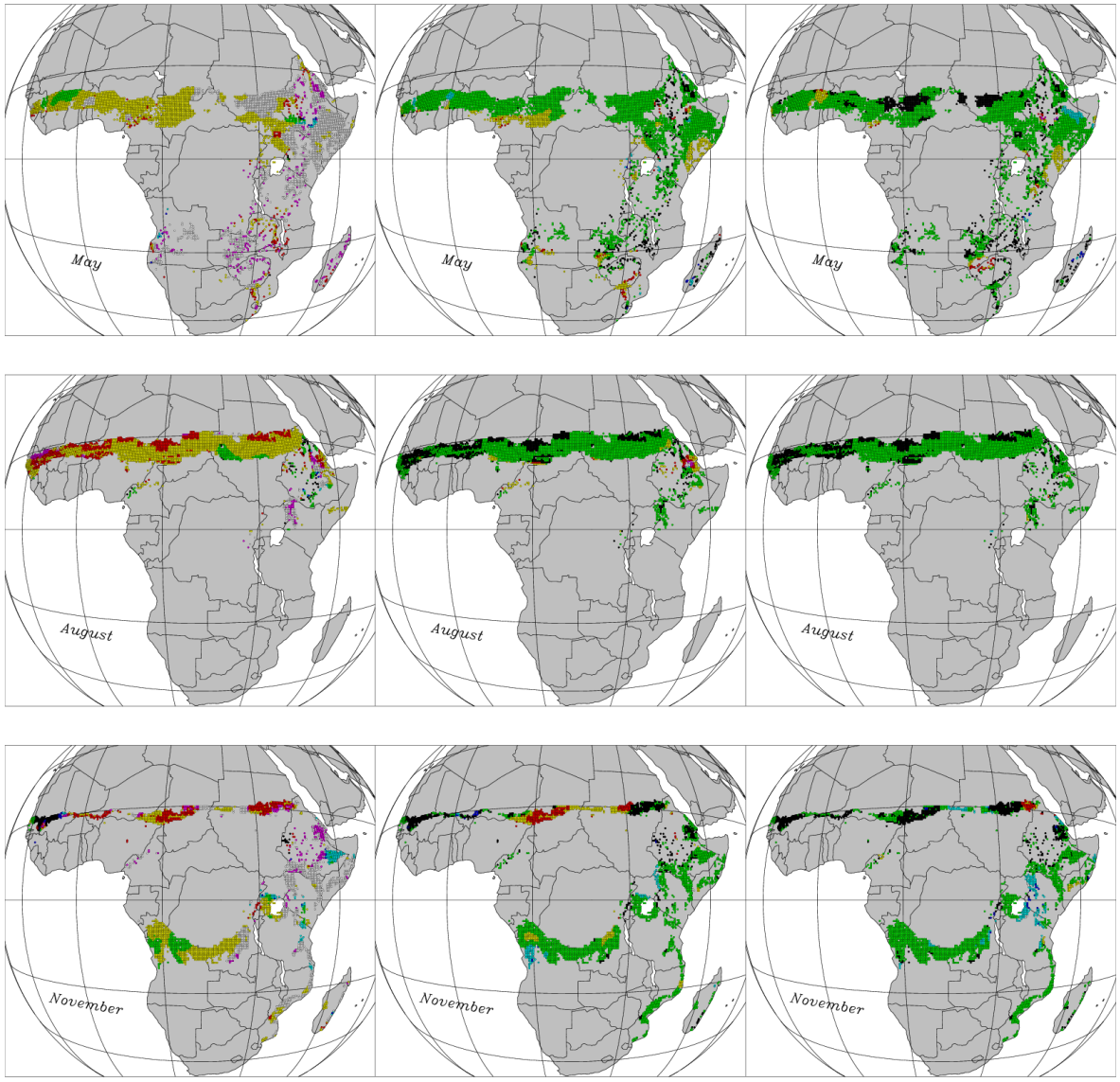
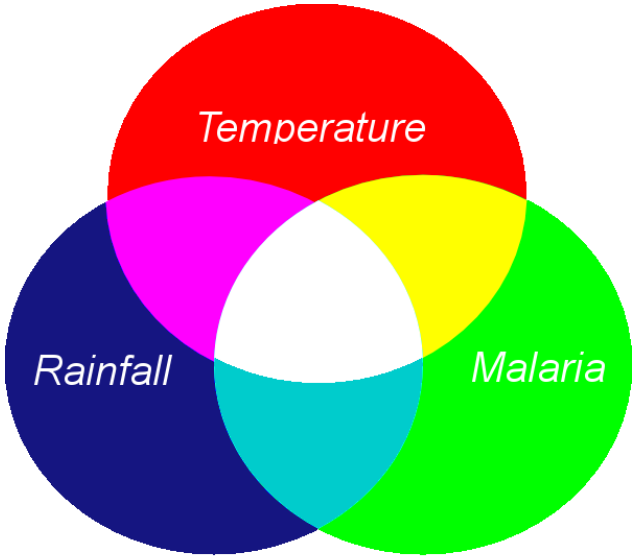


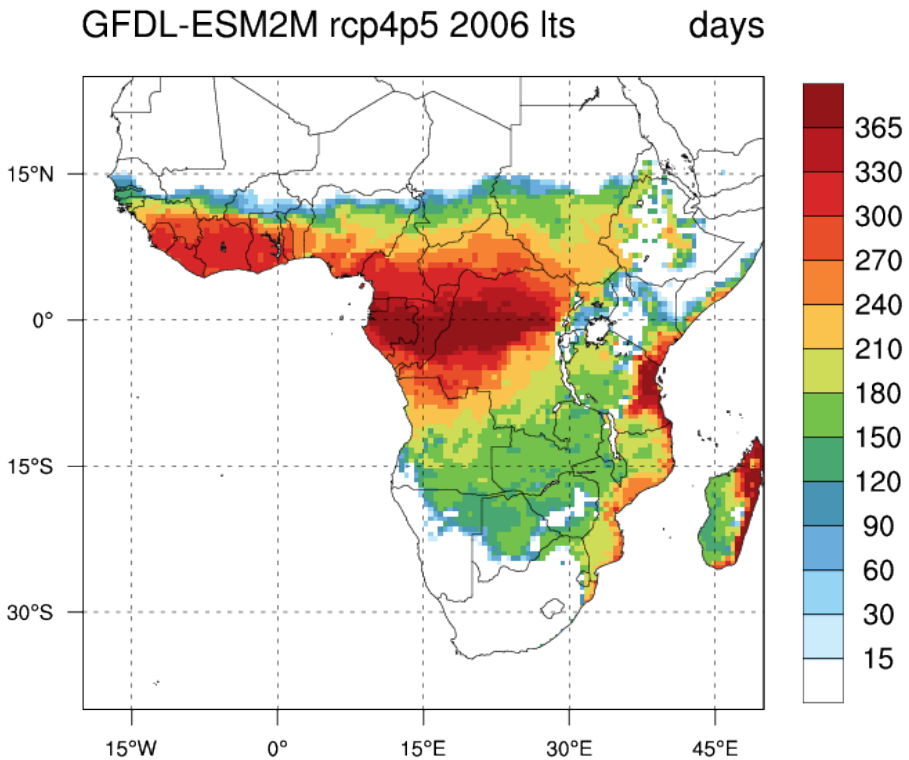




Skill in predicting temperature, rainfall and malaria PR at lead 1-3 months

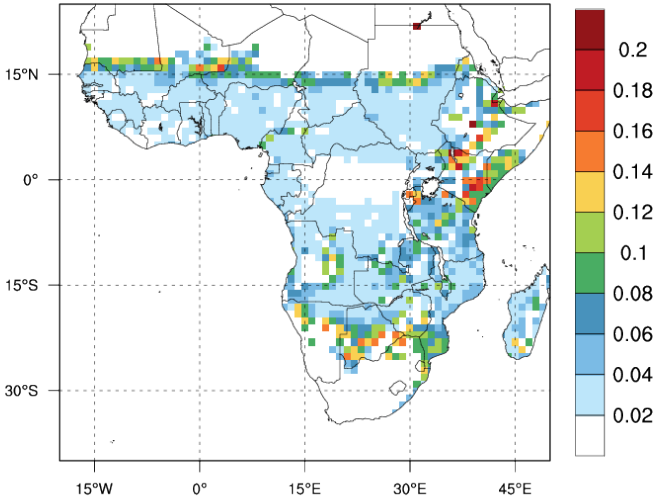




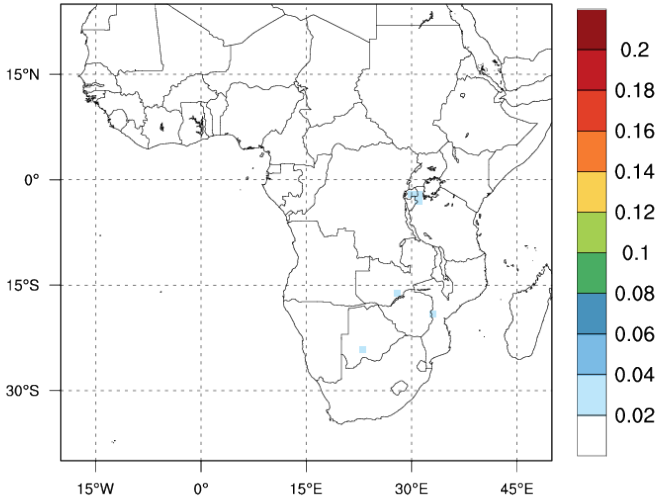


- malaria in West Africa too far south - fault of climate model or malaria model?
- significant interannual variability
- shifts in zone with time

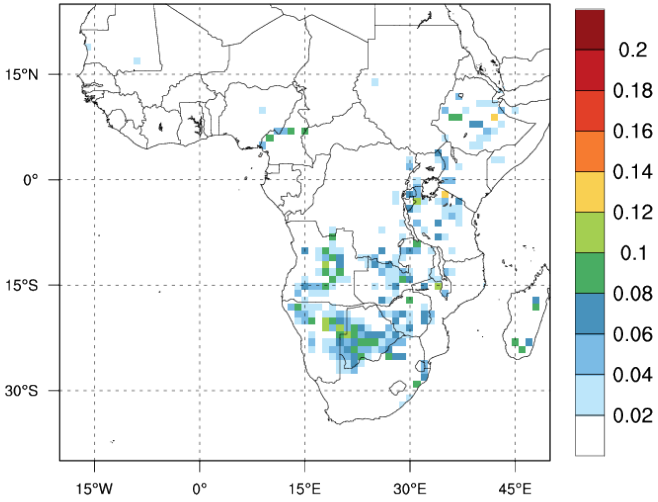
PR standard deviation - correlated



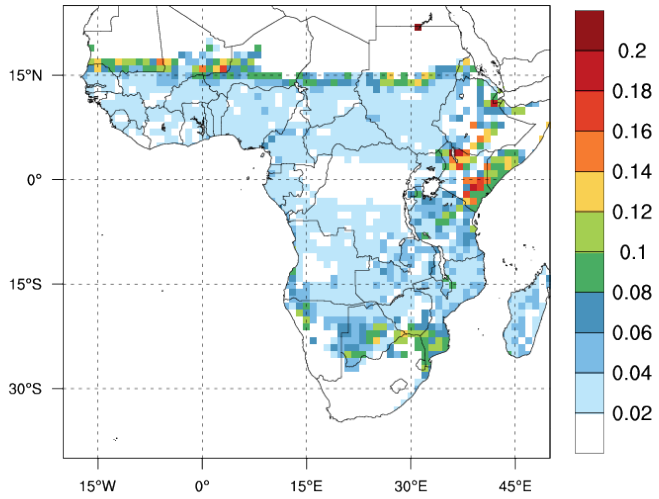
PR standard deviation - random



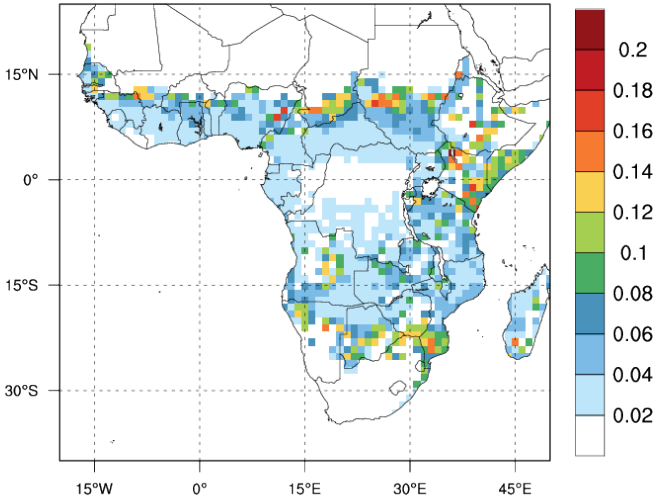
PR standard deviation - rainfix



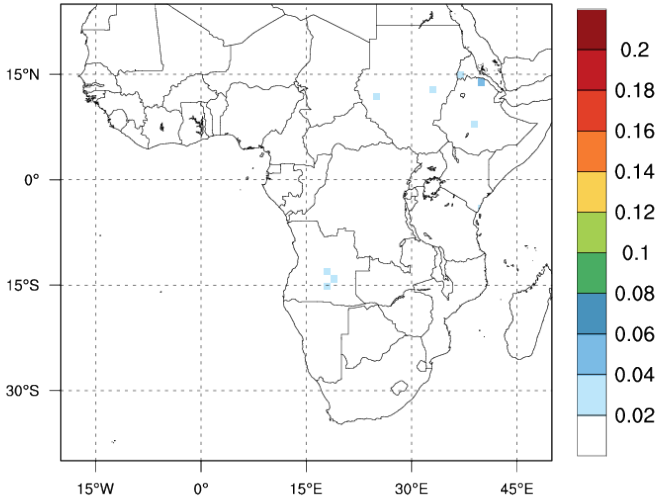
PR standard deviation - tempfix



PR standard deviation - correlated



PR standard deviation - random



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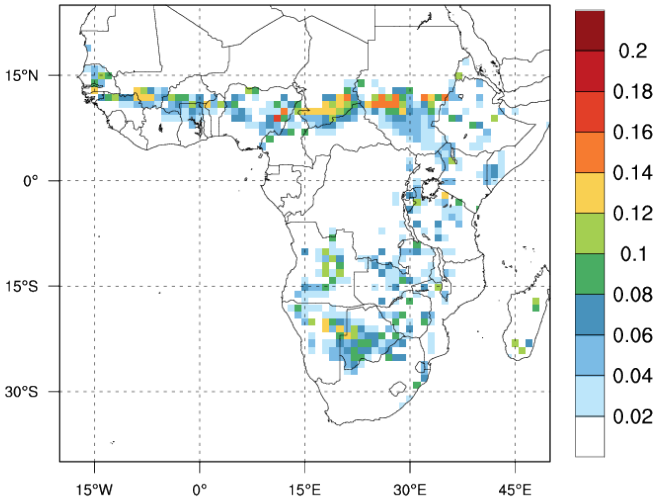
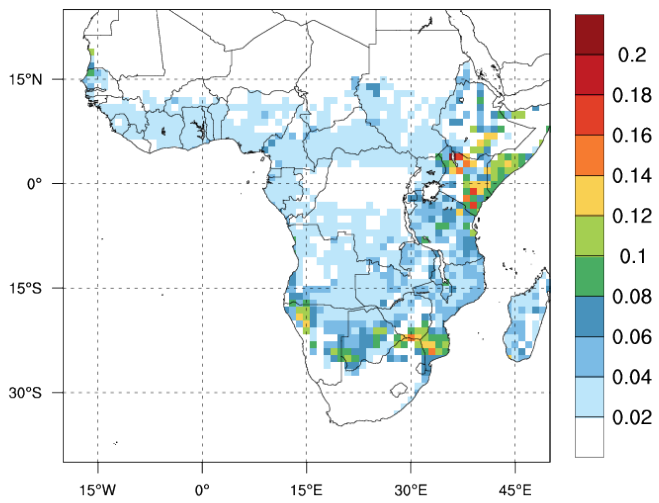
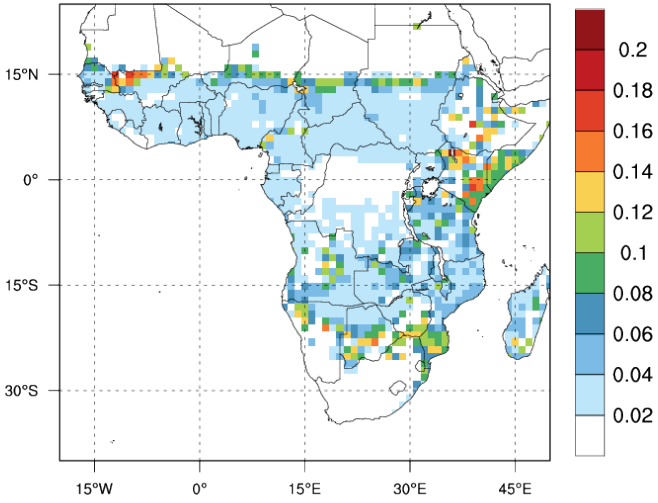


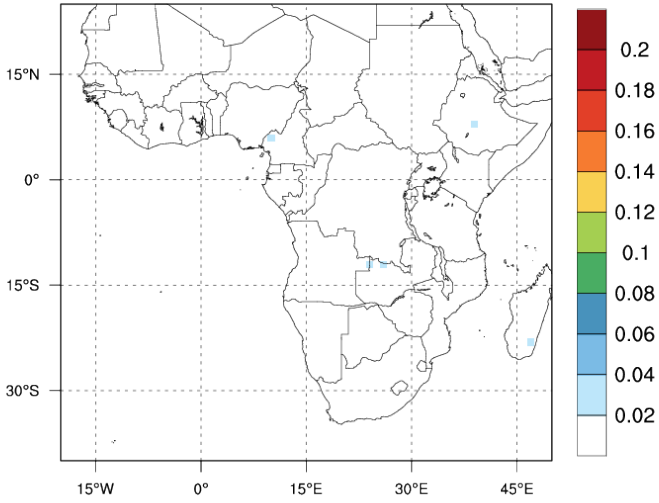
PR standard deviation - tempfix



PR standard deviation - correlated



PR standard deviation - random



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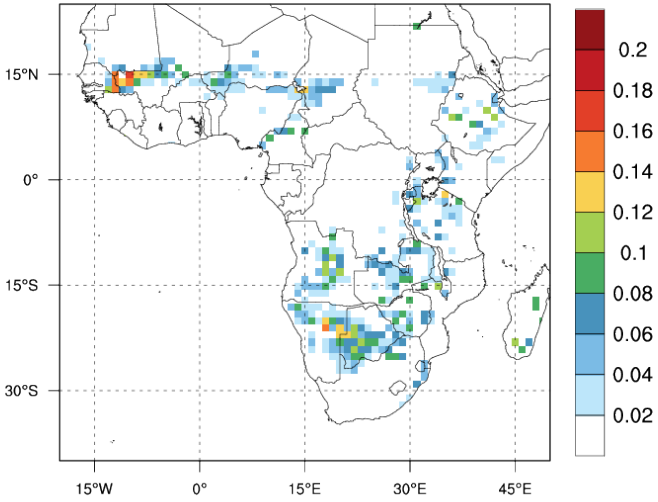

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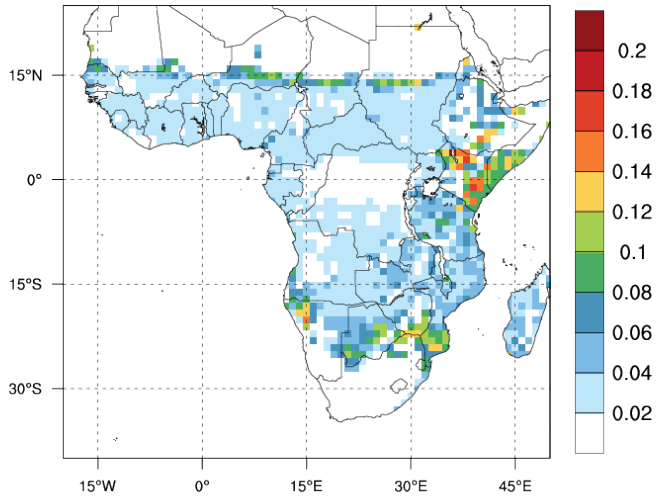

- VECTRI dynamical malaria modelling system
  - community model (schools Arusha, Addis and ICTP)
  - easy to set up for a single location
  - under evaluation
- Can produce zero order EIR-population relation simply through the dilution effect
- Monthly to seasonal prediction - new pilot MEWS with ECMWF
- Under evaluation in Malawi, Uganda, and Rwanda
- Malaria model uncertainty - stochastic perturbations - LMM addition

- Much further evaluation (Uganda, Malawi and Rwanda)
- Different population cohorts to allow dispersive bite rates
- Diverse vector species
- Immunity of population
- Stochastic perturbations
- Migration of population

Thanks to my collaborators:
Ernest Asare KNUST, Ghana - Testing hydrology of VECTRI
Felipe de Jesus Colon-Gonzalez, ICTP - evaluation over Uganda/Rwanda
Rachel Lowe, IC3, Spain - Evaluation over Malawi
Francesca Di Giuseppe, ECMWF, U.K. - Setting up the integrated pilot forecast system
Riccardo Biondi, ICTP - Satellite data of land surface parameters - AMSR-E
Volker Ermert, University of Cologne, Germany - advice on parametrization schemes and literature.
Arne bomblies, Wisconsin, USA - provision of hydremats output.