Regional seasonal forecasting activities at ICTP: climate and malaria

QWeCI meeting, Oct 2012, Kenya. Adrian M Tompkins (tompkins@ictp.it), Volker Ermert, Francesca Di Giuseppe
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Climate variability may offer some potential predictability therefore to help planners:

- short-medium term: prediction of outbreaks in epidemic areas
- short-medium term: potential prediction of seasonal onset in endemic areas
- decadal timescales: potential shift of epidemic areas to higher altitudes [**?**,], shifts in response to rainfall, and associated changing epidemic and endemic patterns.

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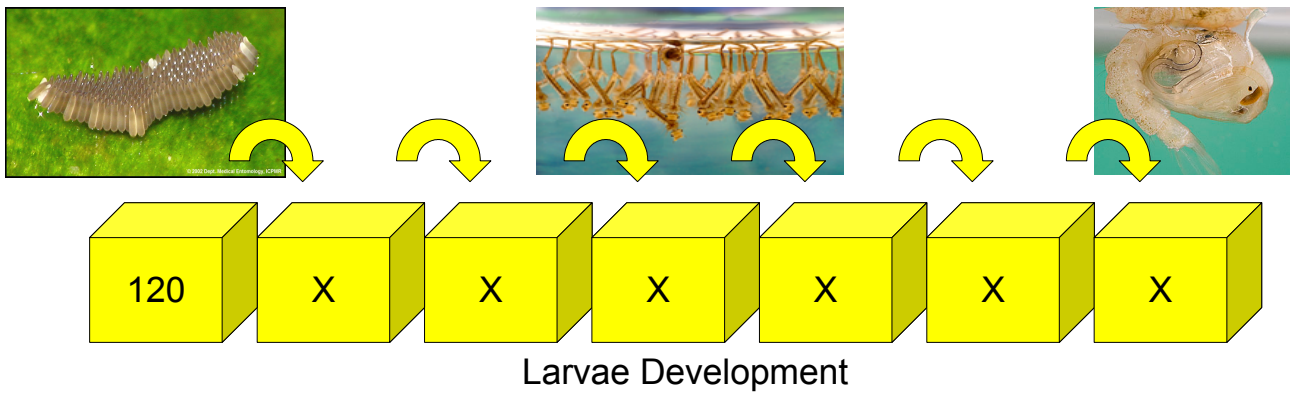
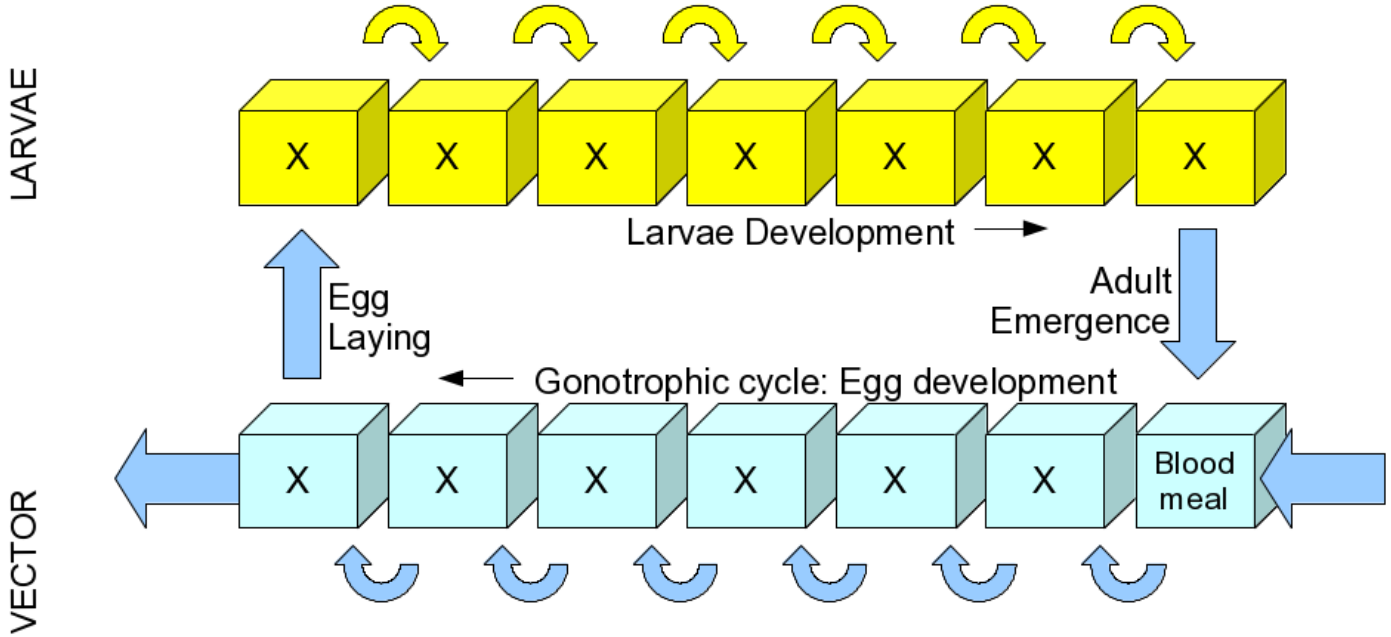
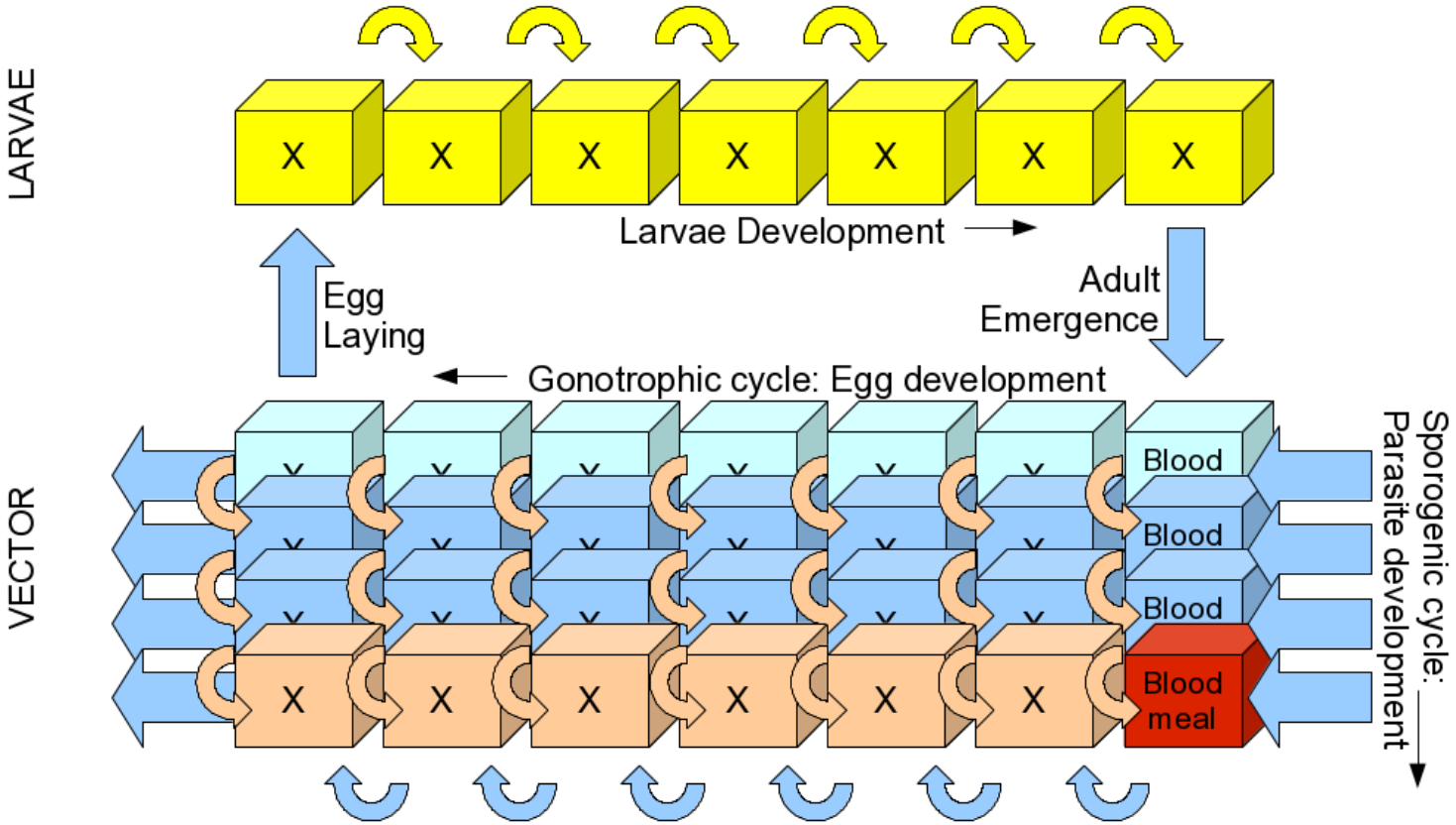
Role of climate change relative to socio-economic factors and interventions remains controversial.

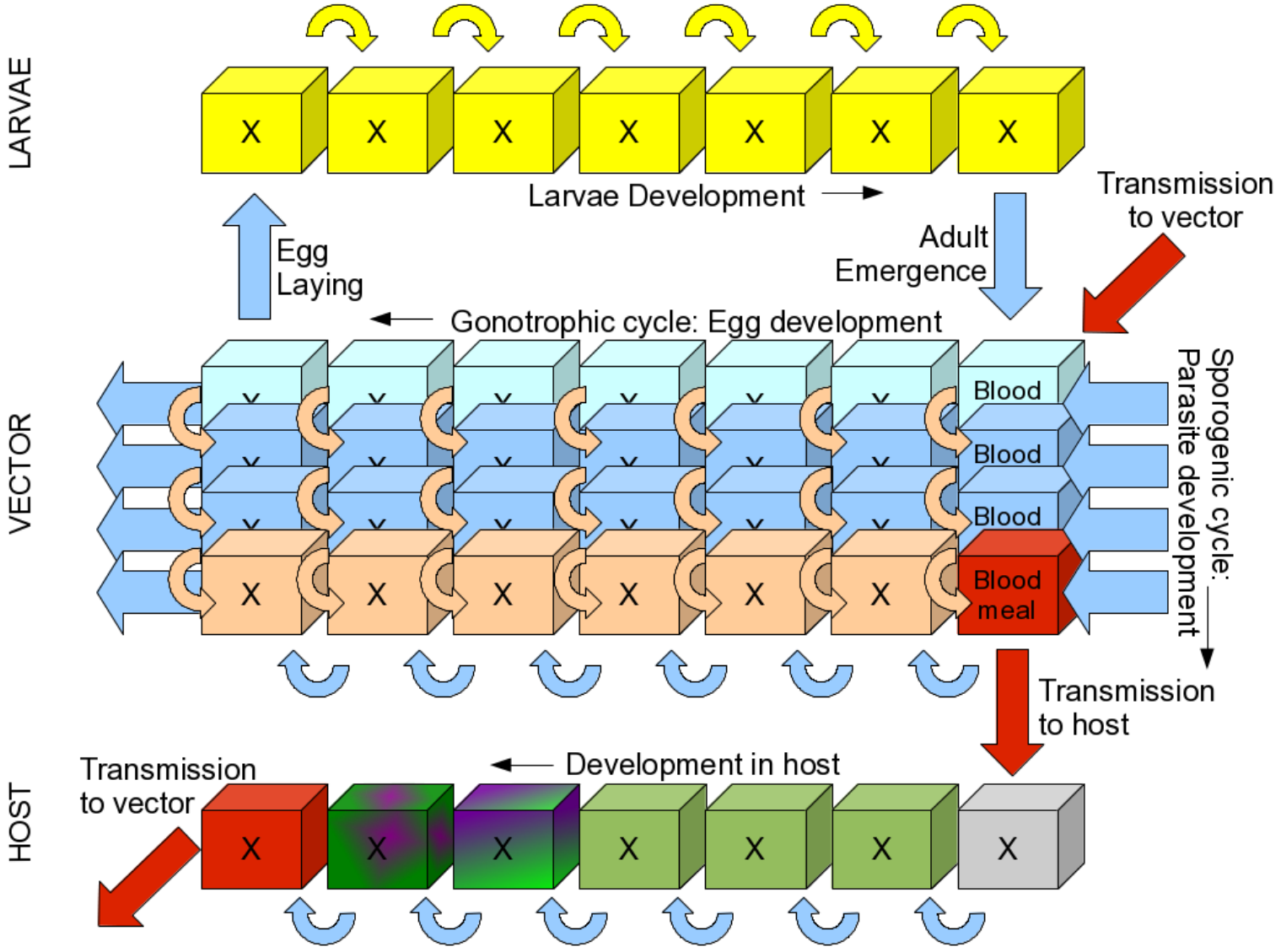
The larvae lifecycle is divided into stages or “bins”. Each model timestep, larvae ’progress’ from left to right, with the rate determined by temperature.



We now add the subclasses for the vector gonotrophic cycle.




LARVAE
X
X
X
X
X
X
X
Larvae Development
Egg
Laying
Adult
Emergence
Gonotrophic cycle: Egg development
VECTOR
Blood
Blood
Blood
Blood
meal
Sporogenic cycle:
Parasite development


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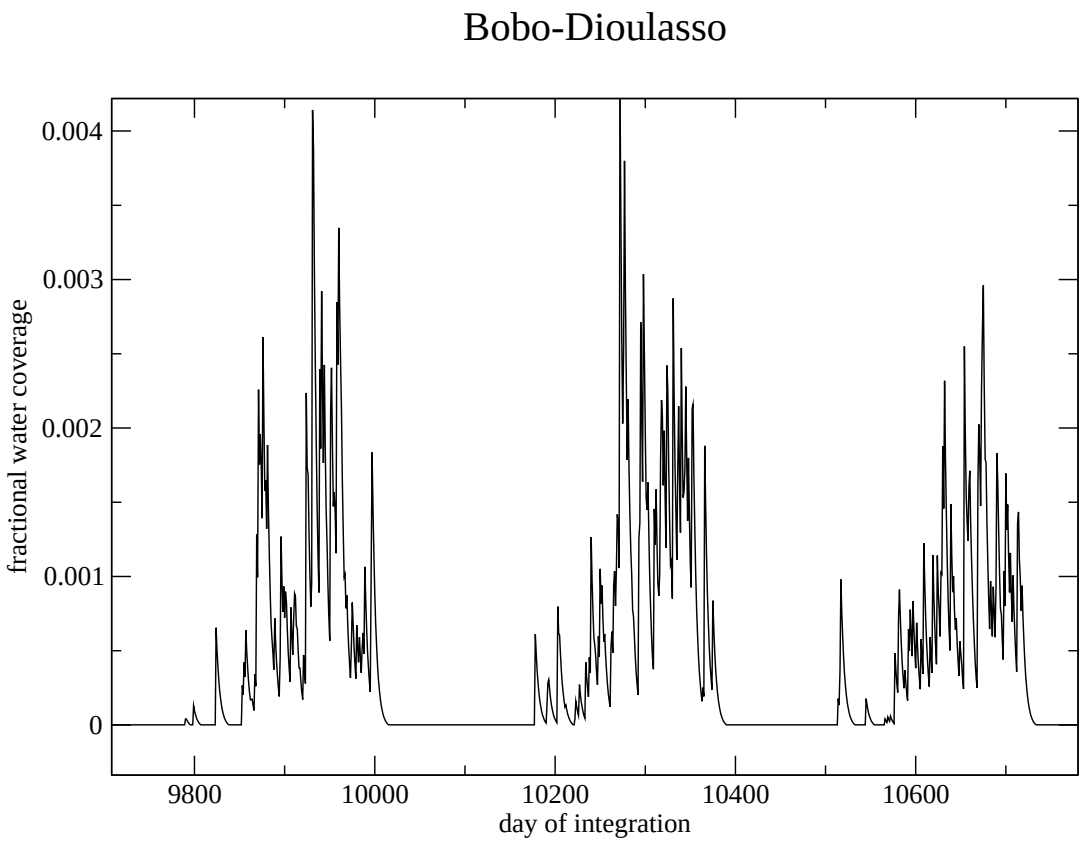
Transmission to vector
Gonotrophic cycle: Egg development
VECTOR
Blood
Blood
Blood
Blood meal
Sporogenic cycle: Parasite development
Transmission to host
Development in host
Transmission to vector
HOST

The rate of change of fractional pond coverage a is given by

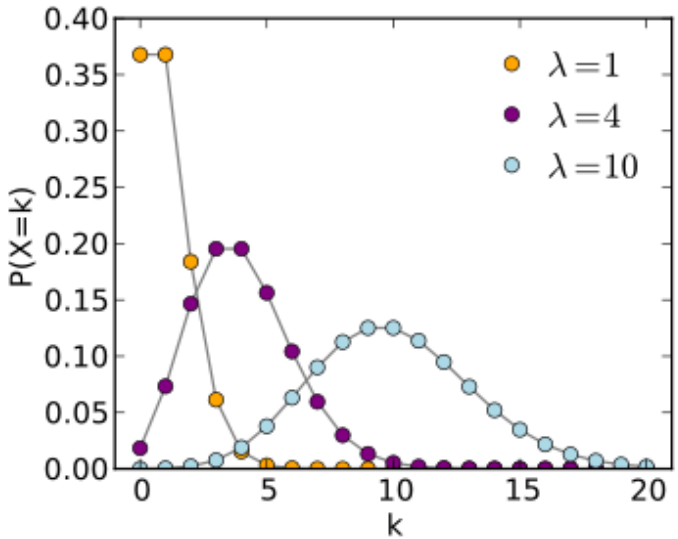
$$\frac{da}{dt} = KP - I - E - \frac{a}{\tau_r} \quad (1)$$

- P is the precipitation rate
- K is related to the aggregate pond/coconut geometry - the puddle parametrization!
- I Infiltration should be related to soil type (coconut=0).
- E Evaporation should be related to meteorology



VECTRI: biting rate

- Mean number of bites per human $B = V_b/D$ biting vectors density/population density
- Assume random distribution (no tastier people!)
- bednet (BN) use can be accounted for $B^* = \frac{V_b}{D(1-BN)}$
- 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^*

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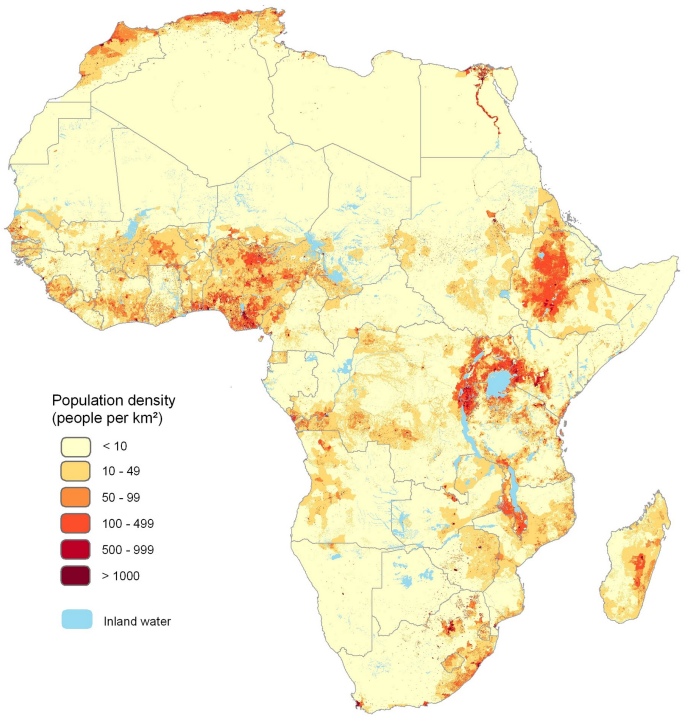
VECTRI: biting rate



- AFRIPOP data used on a 1km grid (thanks Dr. Catherine Linard) or GRUMP on 5km grid (global)
- Present day maps for seasonal forecasting purposes
- For future scenarios, GRUMP/AFRIPOP scaled by AR5 SSP country growth scenarios (no urbanisation trends).
- Data on migration will be extremely important for incorporation in VECTRI (in-country records, lights, mobile phone statistics)

Multiple year gridded runs

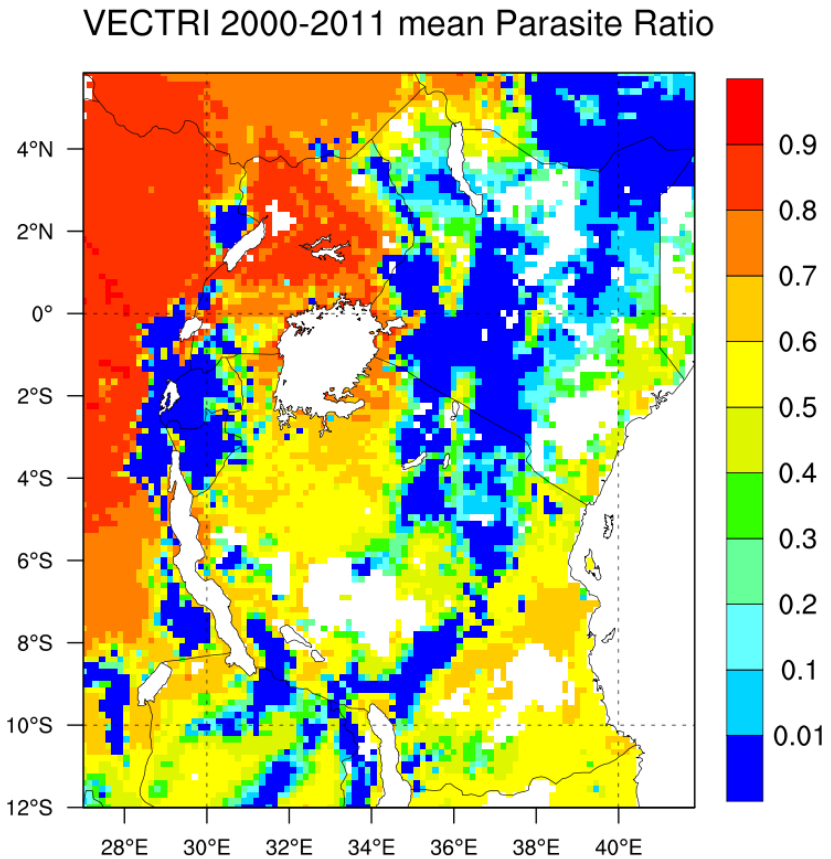
Testing has been conducted in equilibrium modes, and point-wise integrations driven by daily station data compared to a large number of research field studies measuring parasite rate (PR), infectious biting rate (EIR). See Tompkins and Ermert 2012 for details.

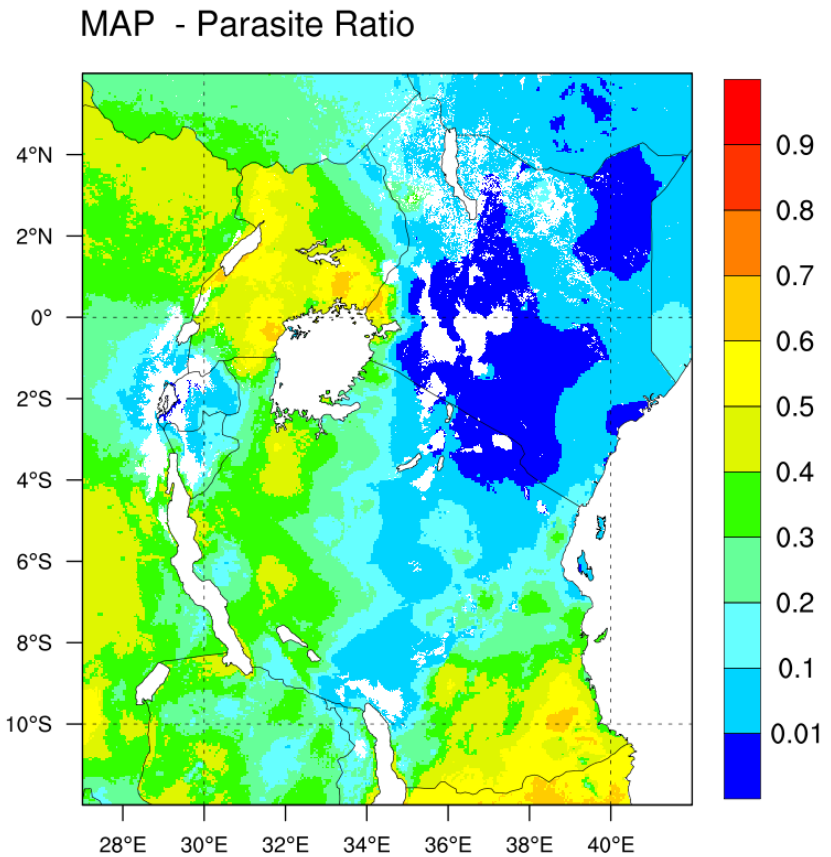
As a move towards the forecast system, VECTRI also run in a gridded mode for different regions of Africa.

Basic Set up:

- Integration 10 years, 10-20km spatial resolution.
- Rainfall data: FEWS RFE 2.0v (10km)
- Temperature data: ERA-Interim T2m (80km) - downscaled using lapse-rate based topography adjustment.

VECTRI vs MAP Parasite Rates (PR)





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

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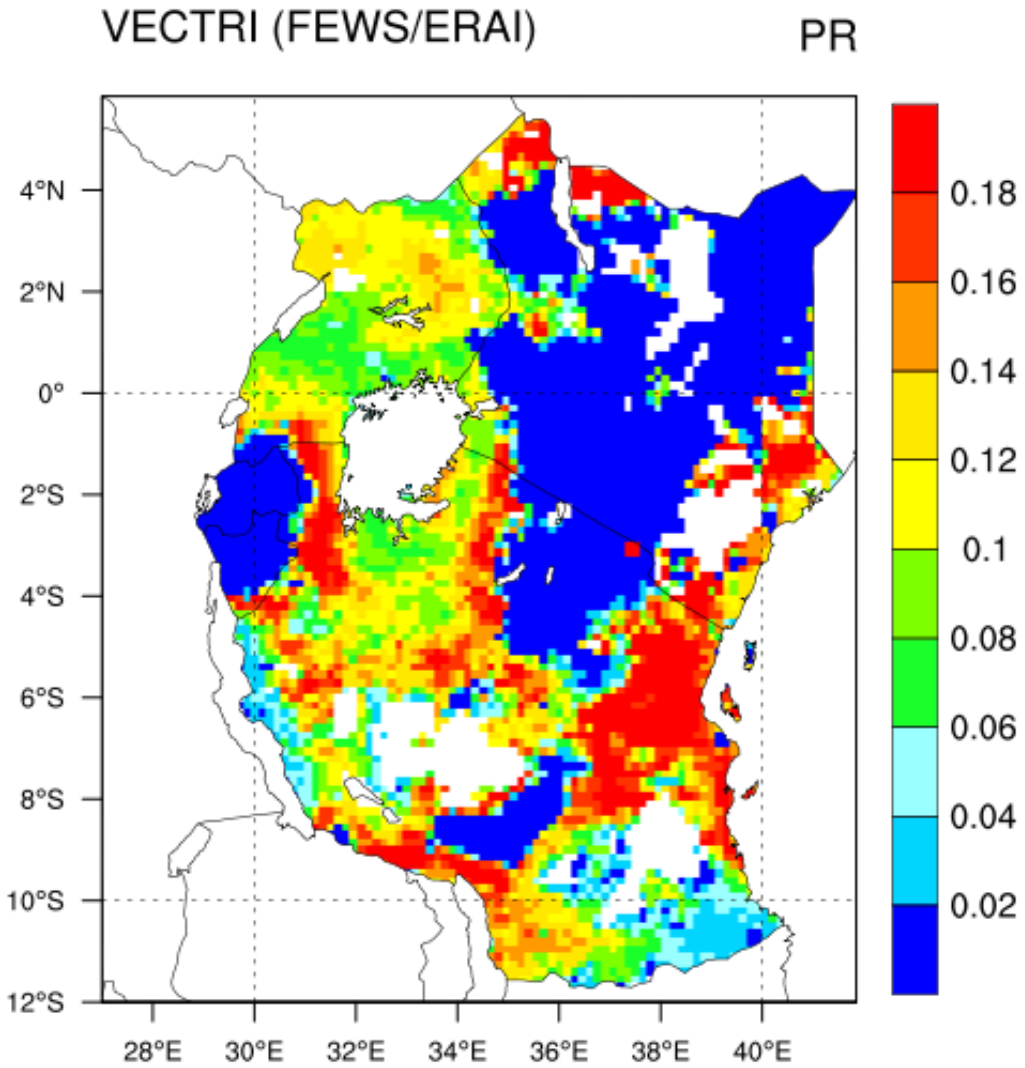
Standard deviation of parasite rate for July



- Variations high in epidemic zones as expected
- "border regions" between lowland endemic and highland epidemic also highlighted; susceptible to climate change?

Force of infection and EIR

Generally the division between epidemic and endemic regions is governed by the force of infection.

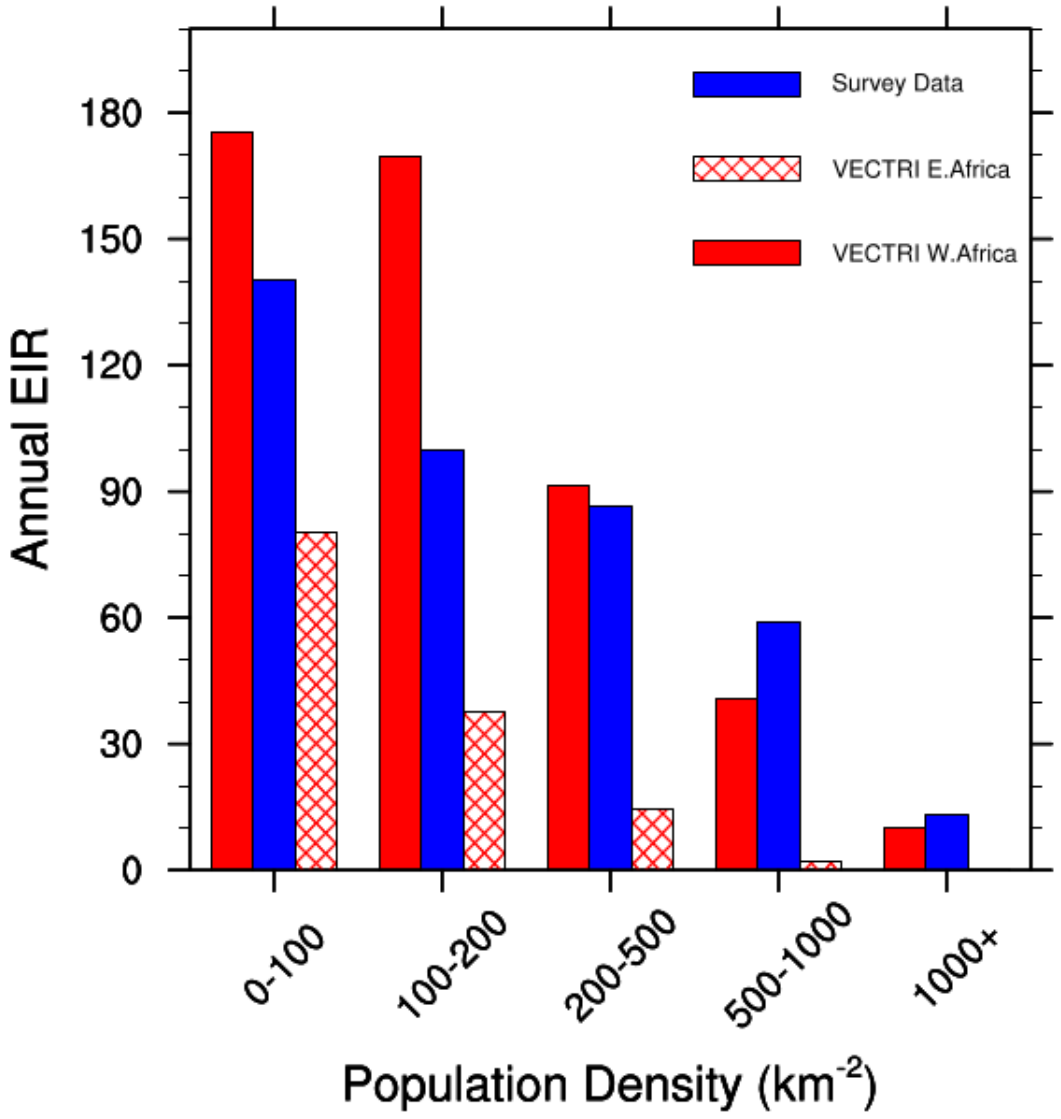
entomological inoculation rate

A good measure of the force of infection is the entomological inoculation rate (EIR) which is the number of infected bites per person per unit time.

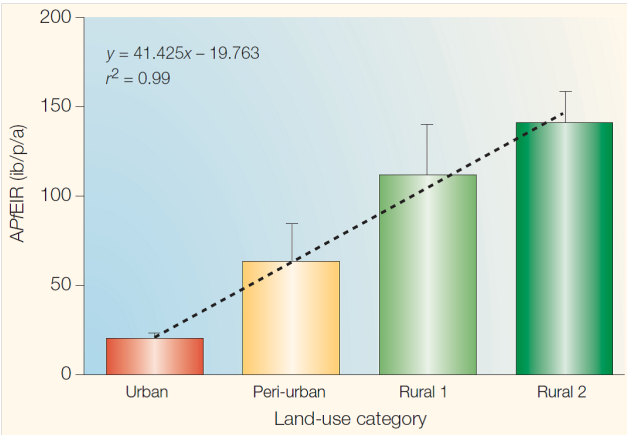
An EIR of around 10 infected bites per year marks the division between epidemic and endemic areas.

EIR - infective bite rates

VECTRI run for E/W Africa compared to Kelly-hope and McKensie (2009)



Hay et al. (2005)



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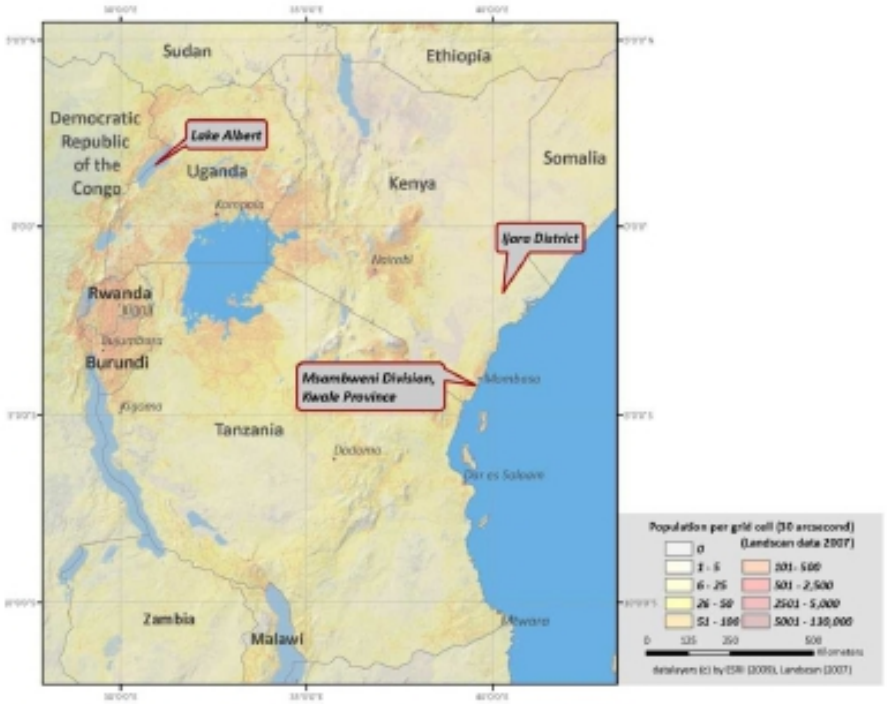
Healthy Futures

Coordinated by David Taylor (formally TCD, now at Singapore national university).

- Runs 2011-2015 (4 year), equal partition between European and African partners
- Examining decadal to century climate-change timescales
- Focussed in Eastern Africa: Tanzania, Rwanda, Uganda, Kenya
- Three target diseases
  - Malaria
  - RVF
  - Schistosomiasis



Has permitted ICTP to build close links to ministry of health in Rwanda and Uganda

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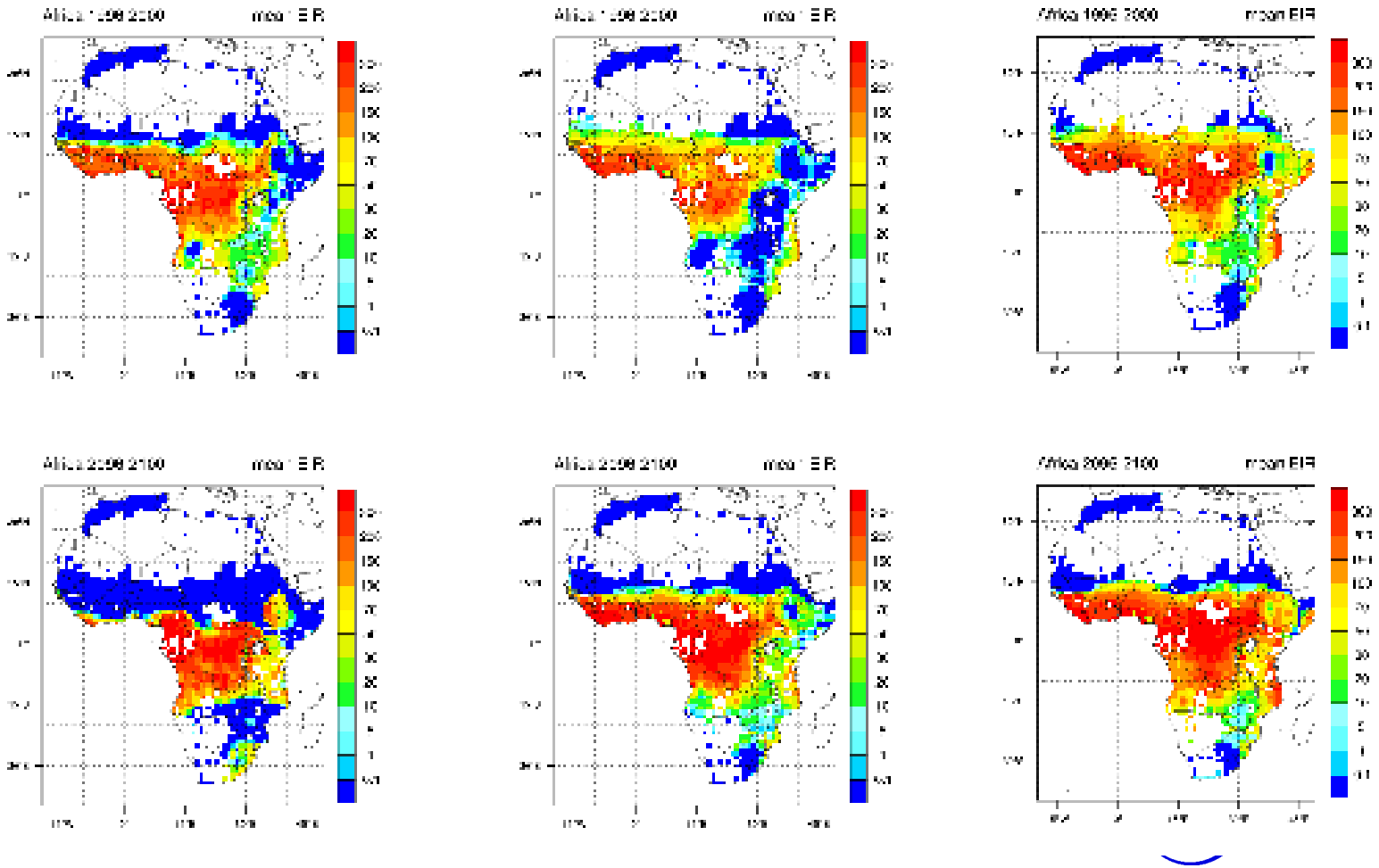
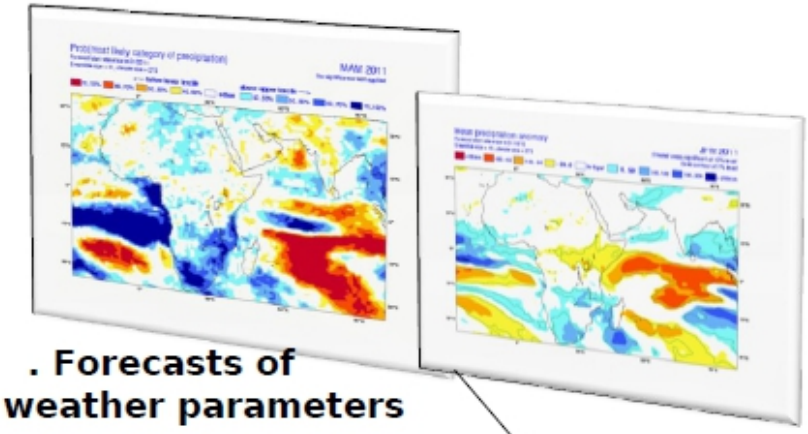
AR4 climate change example

Caveat: only the climate signal from 3 sample models... malaria model is deterministic. Shows highlands becoming endemic - large variation between models.

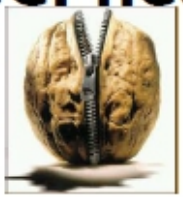


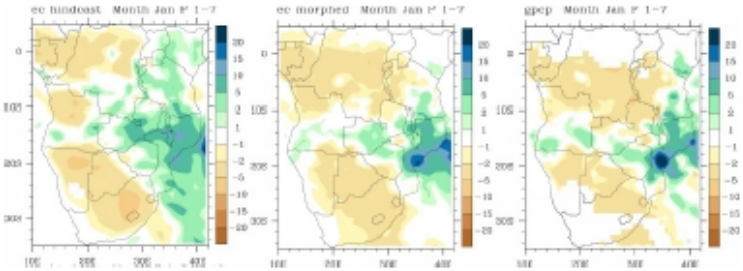
Climate impacts on malaria



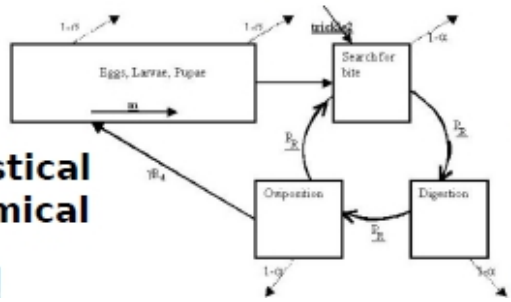
. Forecasts of weather parameters

CONCEPT in a NUTSHELL QWeCI health





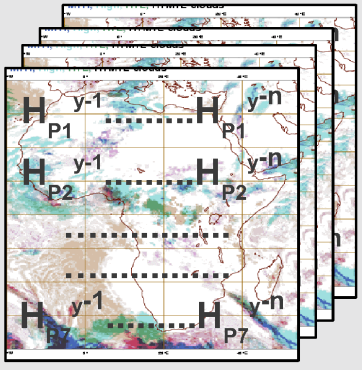
2. Biases corrected statistically and/or dynamically



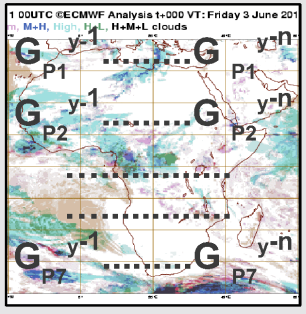
3. Fed into statistical (ICTP) and dynamical

4. To provide ensemble disease risk maps

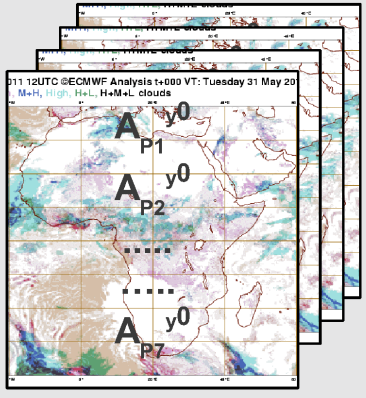
Monthly Hindcast
(*m* - ensemble members)



GPCP and Era-Interim
merged dataset



Monthly forecast
(*p* - ensemble members)



$$\boldsymbol{H}_{anomaly} = \sum_{i=1}^{nEOF} EOF_i^H(x,y)\, PC_i^H(t)$$

$$\boldsymbol{G}_{anomaly}(x,y,t)$$

$$\boldsymbol{A}_{anomaly} = \sum_{i=1}^{nEOF} EOF_i^H(x,y)\;\; PC_i^A(t)$$

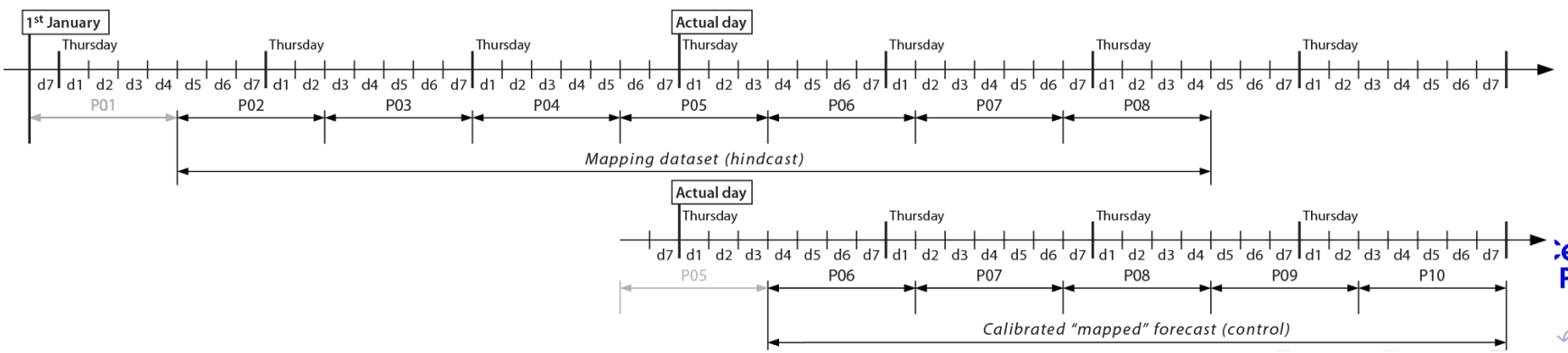
$$EOF_i^M(x,y) = \langle \boldsymbol{G}_{anomaly}(x,y,t)\;\; PC_i^H(t) \rangle_t \quad [i = 1 \ldots . nEOF]$$

Training

Actual forecast

$$\boldsymbol{A}_{anomaly}^{Mapped} = \sum_{i=1}^{nEOF} EOF_i^M(x,y)\;\; PC_i^A(t) \quad [\forall\, p]$$

Mapping



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ECMWF-ICTP IFS-VECTRI coupled system: next steps and timeframe

- Reanalysis to finish by mid-October
- First test hindcast/forecast integration by November
- Evaluate malaria hindcast "climatology" of EIR and PR against field studies and MAP (as in Tompkins and Ermert, 2012)
- Evaluate hindcast products in collaboration with ministries of health in Malawi, Uganda and Rwanda (Jan/Feb 2013)
- Beta launch of IFS-VECTRI at the workshop and colloquium to be held at ICTP in April 2013 (jointly with Healthy Futures and co-sponsored by WMO)
- Extension to multimodel system:
  - Perturbed parameters/parametrizations in VECTRI
  - Extension of seasonal timescales to EUROSIP (4 models)
  - Addition of LMM/LMM2010

FUTURE developments of VECTRI

- Hydrology: Currently very *ah hoc*, but uses framework that allows further development - will include permanent water bodies.
- Population: Migration very simply treated (trickle source), but work on a full migration model underway.
- Immunity: differences between adult and child? Is blocking immunity well understood? Simple SEIR model as a first step.
- Interventions: Bednets are included in a simple way, other interventions to be added.
- DATA
- Open source: model is a community model, already used in Ethiopia.