



The impact of climate change on the malaria risk in Africa



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MALARIA



weather & climate

precipitation
temperature
humidity

mosquitoes

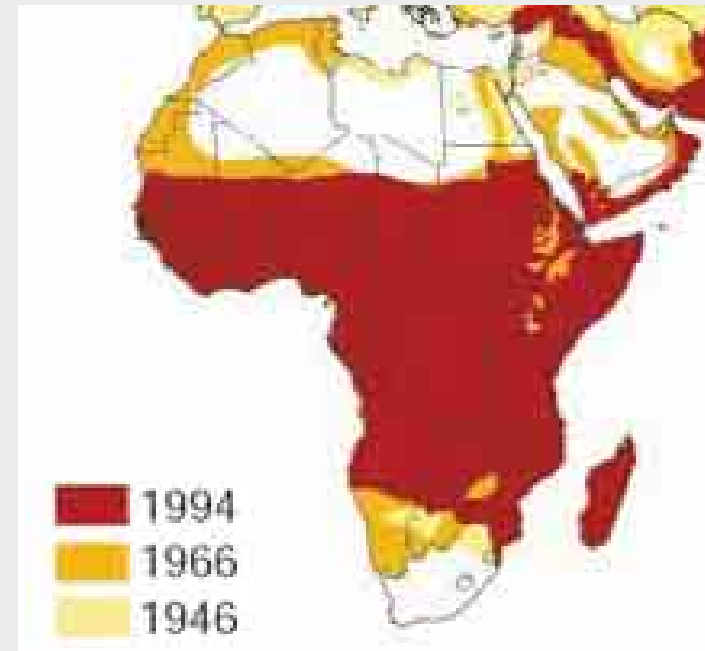
temperature

malaria parasite

malaria

- > 1 million deaths each year
- 90% sub-Saharan Africa
- mostly children

Malaria risk

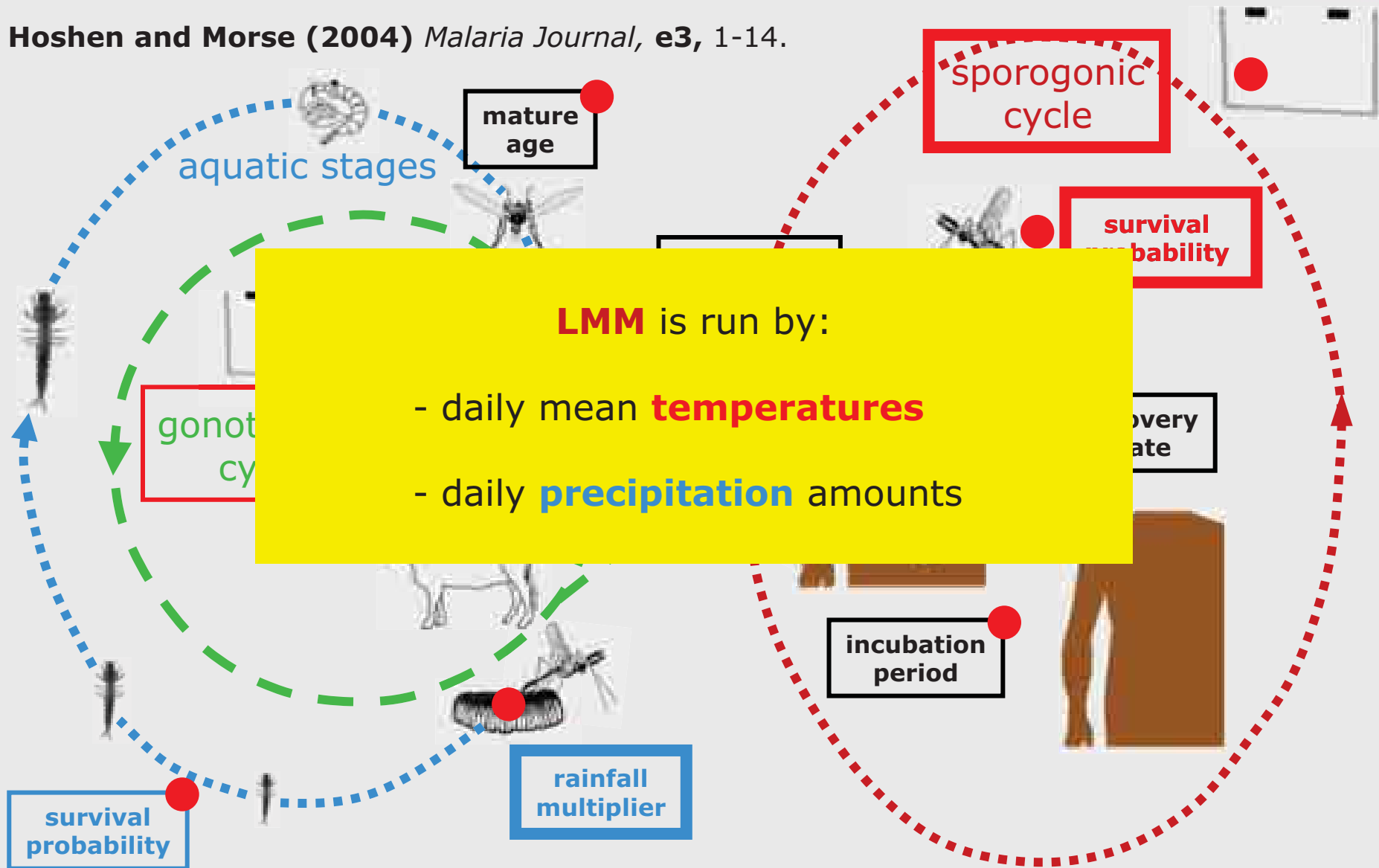


source: Sachs und Malaney (2002), *Nature*

How does the spread of malaria evolve in a warmer future climate?

„LIVERPOOL MALARIA MODEL (LMM)“

Hoshen and Morse (2004) *Malaria Journal*, e3, 1-14.



Modification of the **LIVERPOOL MALARIA MODEL (LMM)**



- Literature survey \Rightarrow entomological & parasitological malaria data



■ egg deposition (E)

- number of produced eggs (E_p)
- rainfall conditions \Rightarrow **fuzzification**

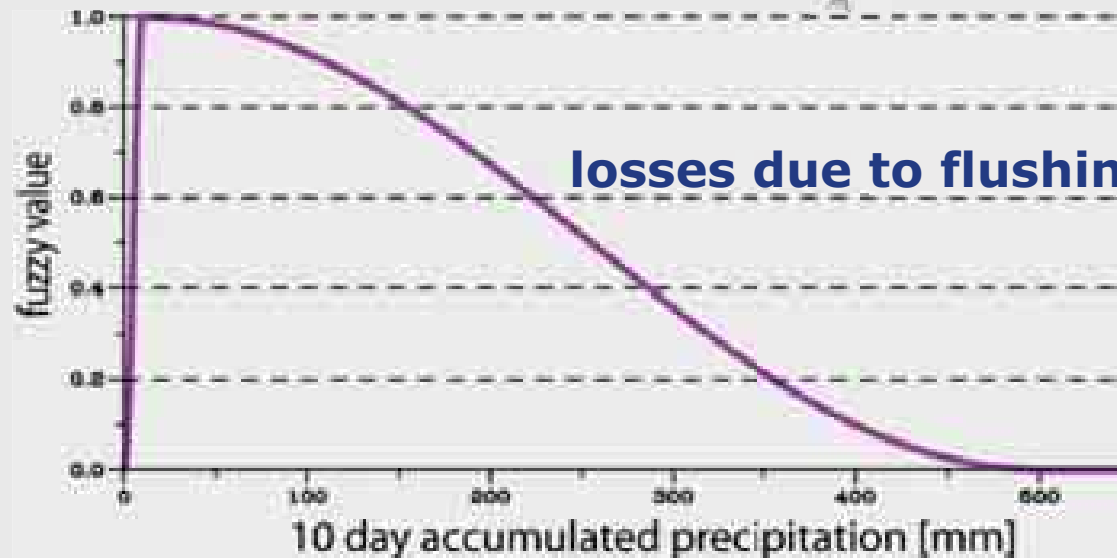
■ survival immature mosquitoes (S)

- max. 10% pass the egg, larval, and pupal stages $\Rightarrow S_{max}$
- rainfall conditions \Rightarrow **fuzzification**



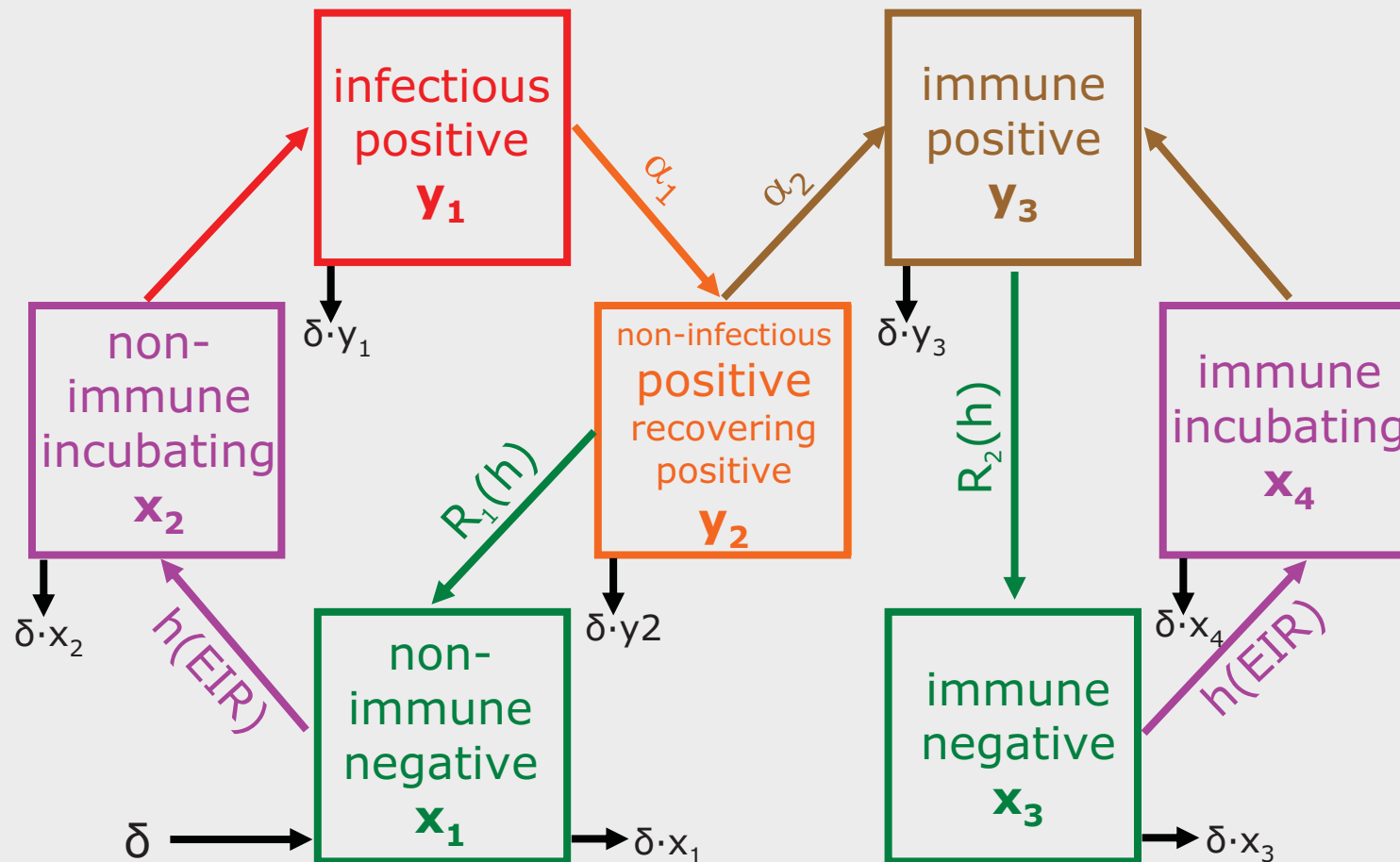
$$E = E_p * VAL_{fuz}$$
$$S = S_{max} * VAL_{fuz}$$

dry conditions



GARKI MODEL


- mathematical model of malaria transmission from the Garki project
- compartment model including immunity
- 7 coupled differential equations
- data input: e.g., **E**ntomological **I**noculation **R**ate (**EIR**)
- simulates the **age-distribution** of the malaria prevalence



Dietz, Molineaux, & Thomas (1974) *Bull. WHO*, 50, 347-357.

Performed LMM runs

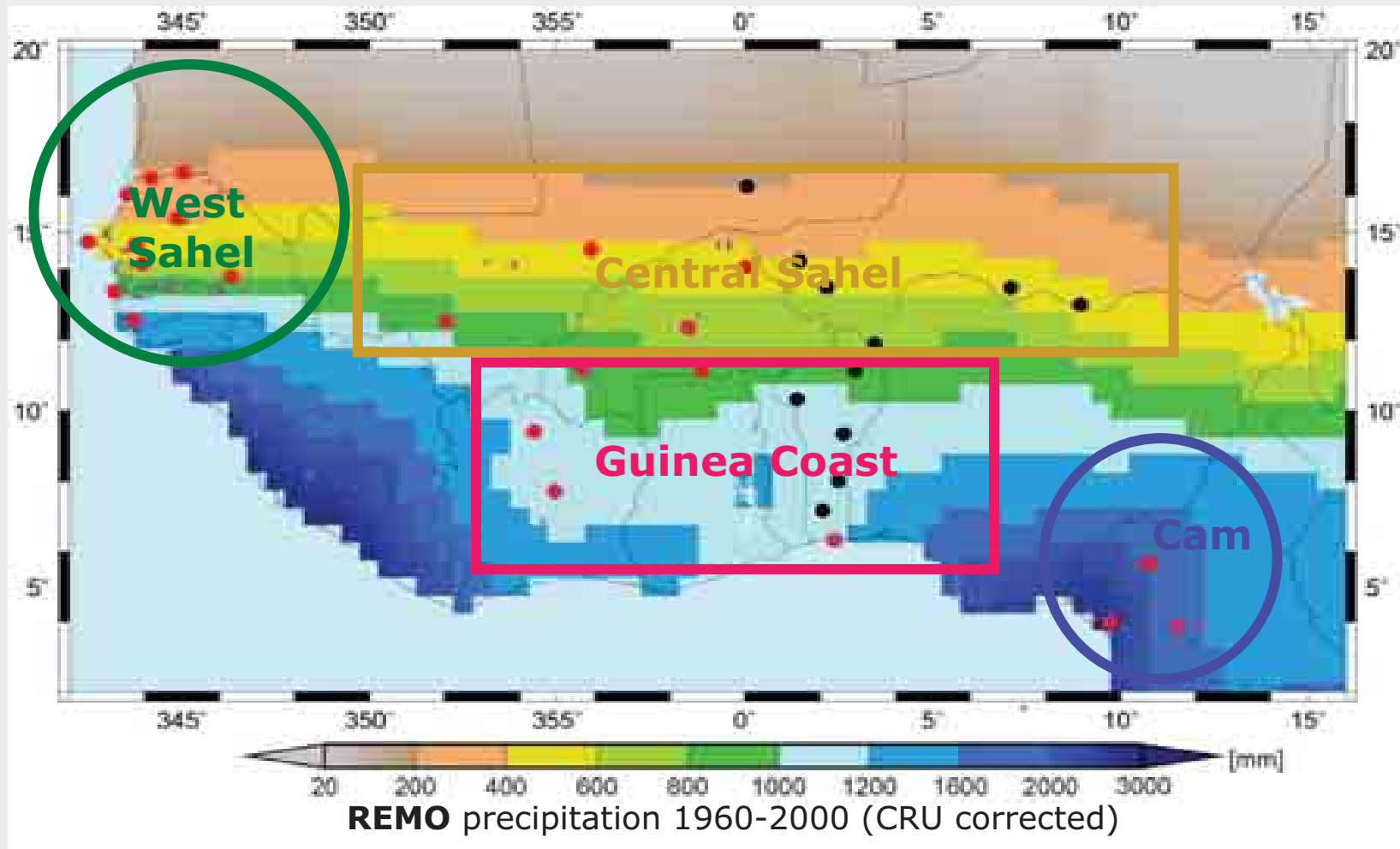


<i>period</i>	<i>LMM input data</i>	<i>forcing</i>	<i>land use & land cover</i>	<i>ensemble</i>
1973-2006	station observations	—	—	—
1960-2000	REgional climate MOdel	increasing GHGs	constant (early 1990s)	1 2 3
2001-2050	 0.5° resolution	A1B	stochastic changes in line with FAO	1 2 3
2001-2050		B1	weaker changes	1 2 3

The LMM is forced by:

- daily mean **temperature**
- daily **precipitation**

LMM VALIDATION in West Africa (1973-2006)

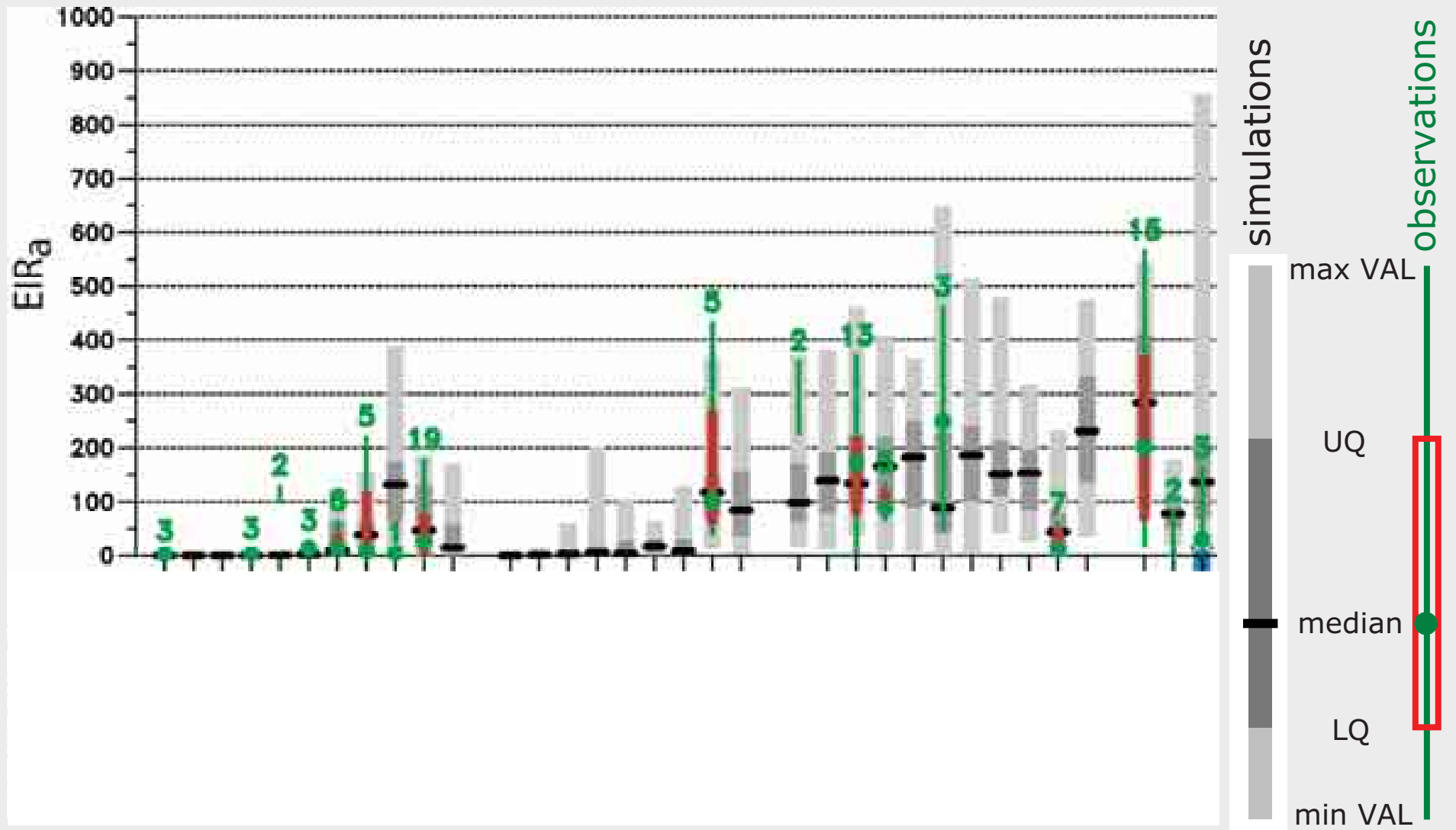


- meteorological data
- malaria & meteorological data
- rural field sites of malaria studies

LMM VALIDATION in West Africa (1973-2006)



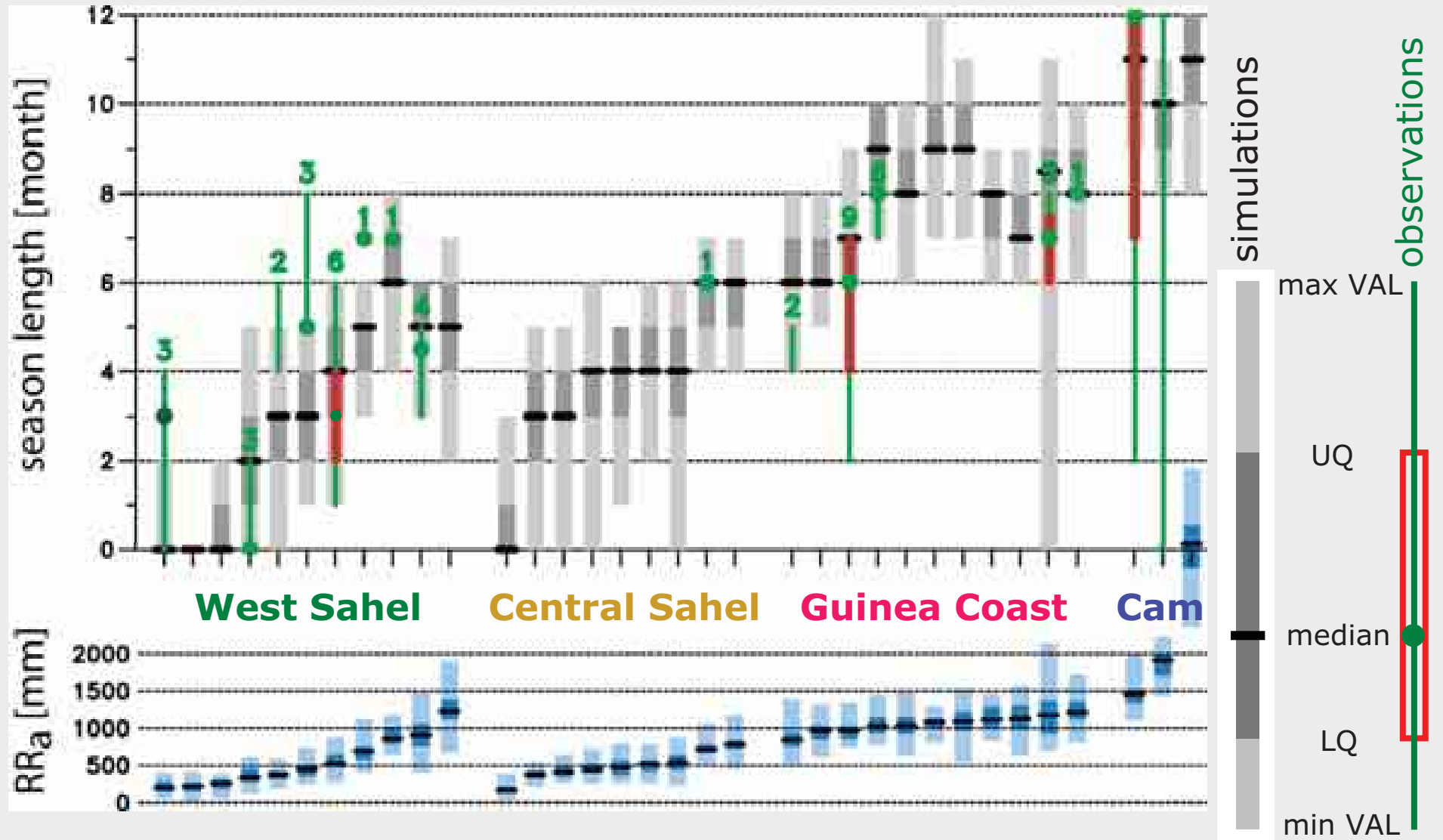
EIR_a: **a**nnual **E**ntomological **I**noculation **R**ate,
i.e. the number of infectious mosquito bites per human per year



LMM VALIDATION in West Africa (1973-2006)



Seasonality: length of the malaria season





Temperature and
precipitation changes
projected by **REMO**



(data input of the LMM)

Paeth et al. (2009) Regional climate change in tropical and northern Africa due to greenhouse forcing and land-use changes. *Journal of Climate*, 22, 114-132.

REMO: temperature (T) and temperature change (ΔT)

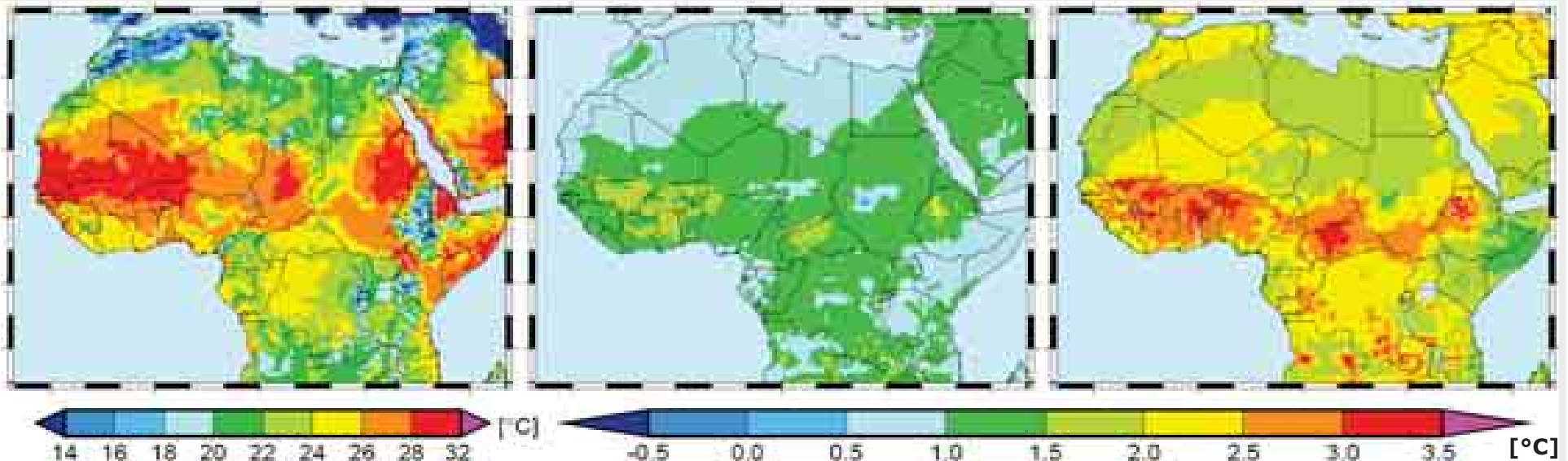


A1B

T: 1960-2000

ΔT : 2021-2030

ΔT : 2041-2050



corrected by
ERA-40 data

- temperature is increasing
- mostly pronounced around 10°N

REMO: **precipitation** (RR) and change of precipitation (Δ RR)

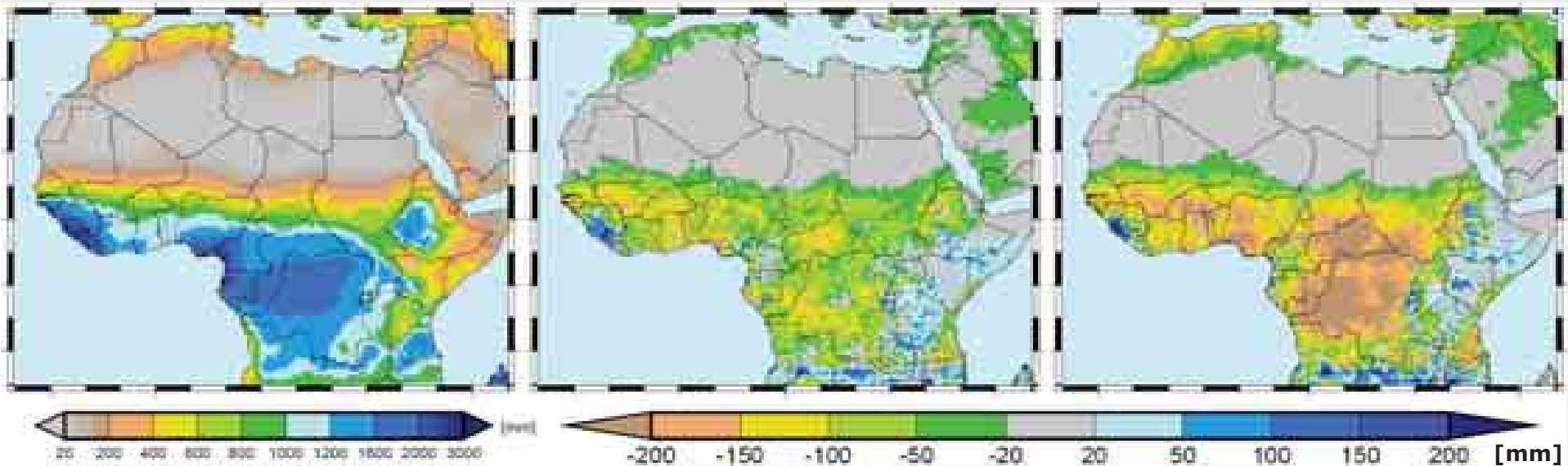


A1B

RR: 1960-2000

Δ RR: 2021-2030

Δ RR: 2041-2050



corrected by
CRU data

- precipitation **decreases** in **West Africa** and **Central Africa**
- precipitation is **increasing** around the **Guinean Mountains** and **East Africa**



Changes in the modelled
annual **E**ntomological **I**noculation **R**ate
projected by **LMM**
based on **REMO** data

LMM: **annual EIR** (EIR_a) and its change (ΔEIR_a)

↳ i.e. the number of infectious mosquito bites per human per year

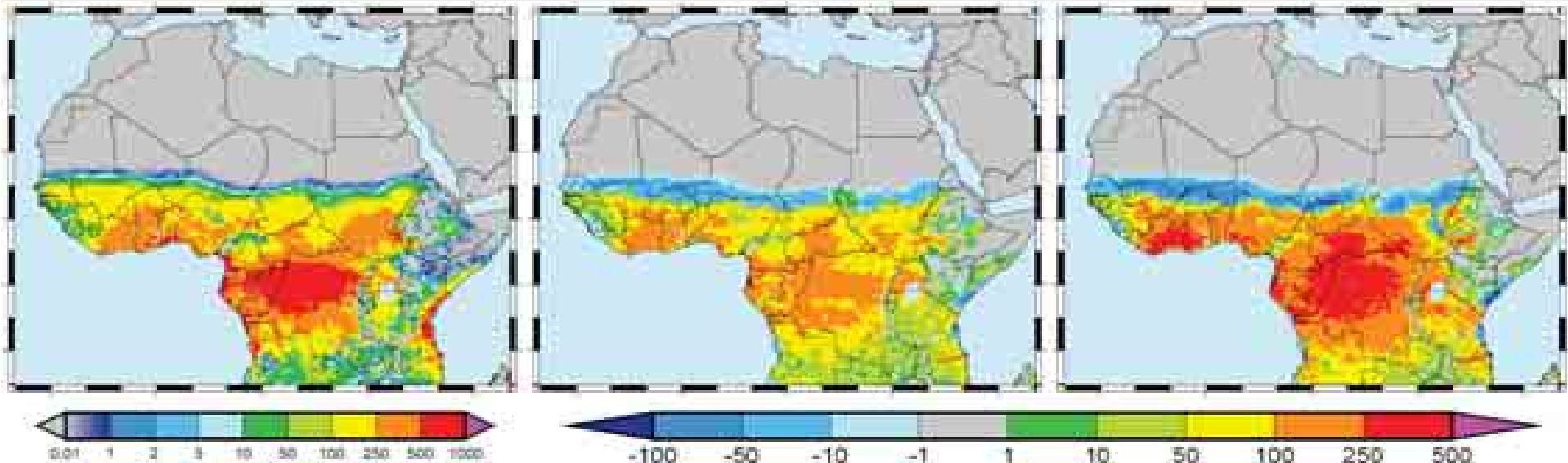


EIR_a : **1960-2000**

ΔEIR_a : **2021-2030**

A1B

ΔEIR_a : **2041-2050**



- malaria transmission is **decreasing** in the Sahelian & Sudanian zone
- EIR **increases** in most parts of **Equatorial Africa**

LMM: σ of **annual EIR** ($\sigma(\text{EIR}_a)$) and its change ($\Delta\sigma(\text{EIR}_a)$)

↳ standard deviation \Rightarrow interannual variability

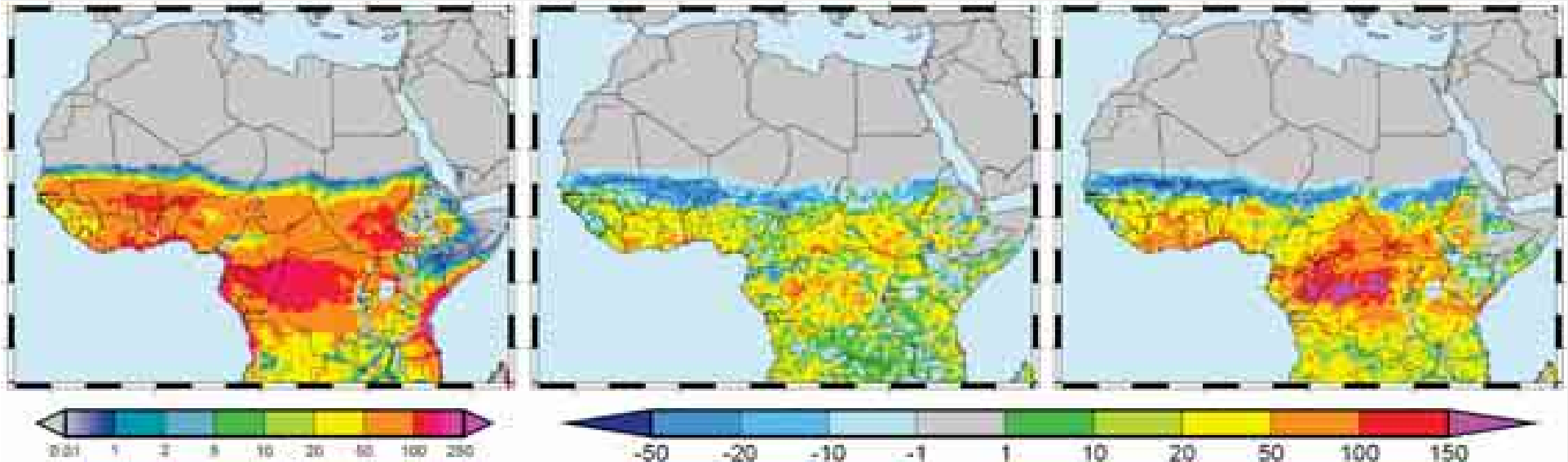


A1B

$\sigma(\text{EIR}_a)$: **1960-2000**

$\Delta\sigma(\text{EIR}_a)$: **2021-2030**

$\Delta\sigma(\text{EIR}_a)$: **2041-2050**

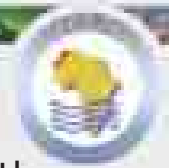


- malaria transmission is decreasing in the Sahelian zone
- EIR increases in most parts of Equatorial Africa



Changes in the simulated
malaria **prevalence**
projected by the **Garki model**
based on **LMM** data

Garki model: **child prevalence** (PR_{2-10}) and its change (ΔPR_{2-10})



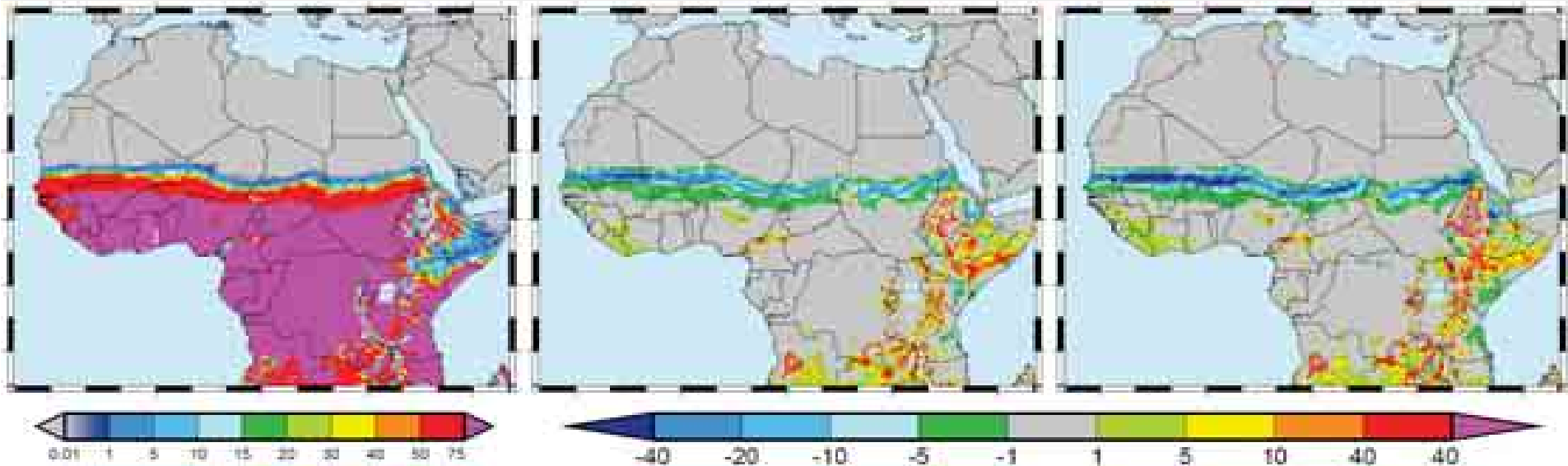
↳ i.e. the proportion of children (2-10 years) that are carrier of the malaria parasite

A1B

PR_{2-10} : **1960-2000**

ΔPR_{2-10} : **2021-2030**

ΔPR_{2-10} : **2041-2050**



■ PR_{2-10} decreases in the Sahel

■ PR_{2-10} increases in East Africa

Garki model: **prevalence max. (PR_{max})** and its change (ΔPR_{max})



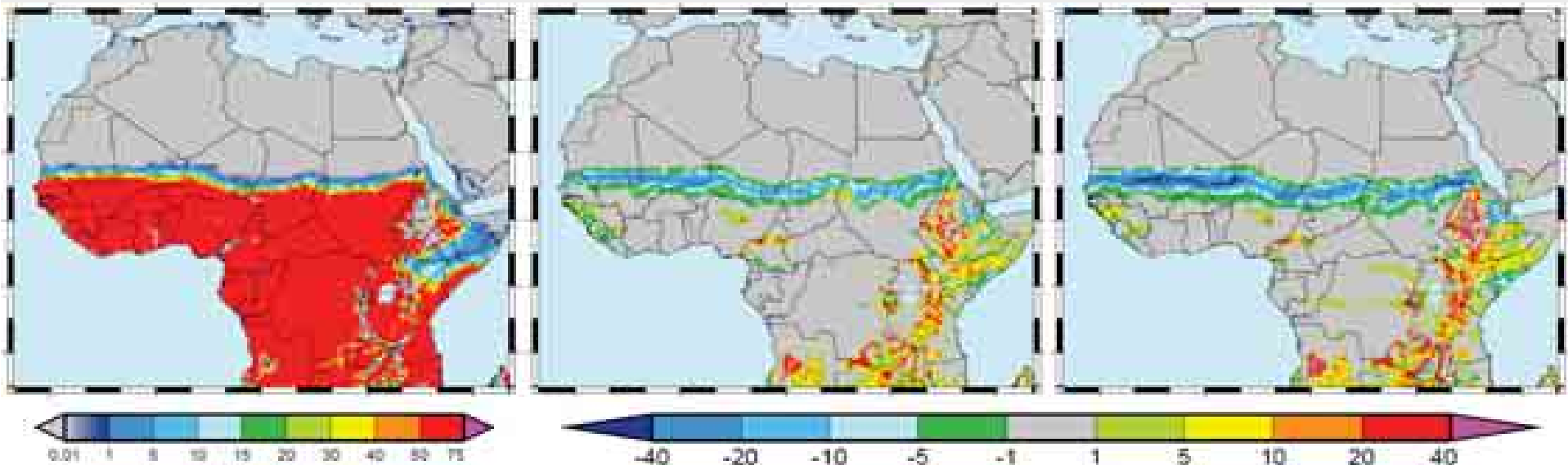
↳ i.e. the proportion of the population that is carrier of the malaria parasite

A1B

PR_{max} : 1960-2000

ΔPR_{max} : 2021-2030

ΔPR_{max} : 2041-2050



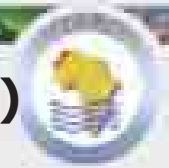
- PR_{max} decreases in Sahelian zone
- PR_{max} it increases in Eastern Africa

Garki: σ of **prevalence max.** ($\sigma(\text{PR}_{\text{max}})$) and its change ($\Delta\sigma(\text{PR}_{\text{max}})$)



standard deviation

⇒ interannual variability of malaria transmission ⇒ epidemics

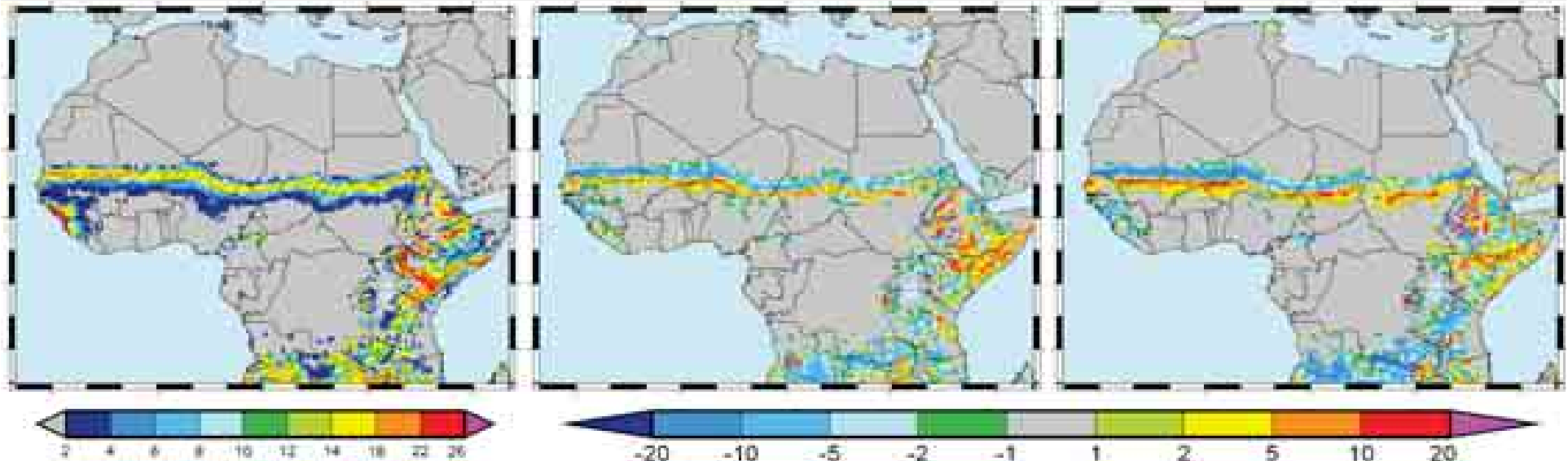


A1B

$\sigma(\text{PR}_{\text{max}})$: **1960-2000**

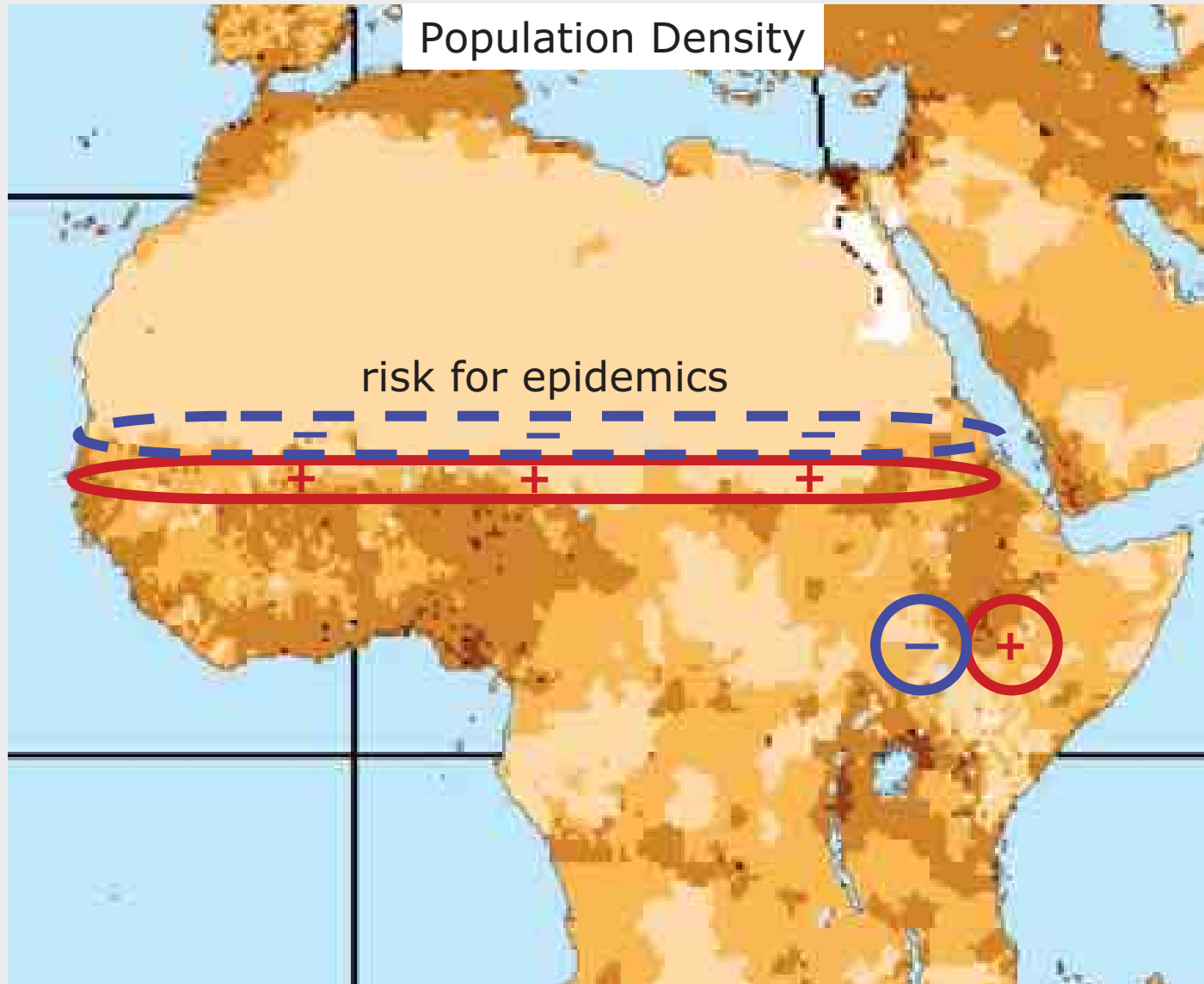
$\Delta\sigma(\text{PR}_{\text{max}})$: **2021-2030**

$\Delta\sigma(\text{PR}_{\text{max}})$: **2041-2050**



- σ decreases (increases) in the N(S)-Sahelian zone and in parts of East Africa
 - risk for malaria epidemics changes

MALARIA EPIDEMICS



source: CIESIN Columbia University; **gridded population of the world (GPW)**, version 3

FUTURE PROSPECTS



■ Changes in the **malaria season**

- LMM vs. MARA Seasonality model

■ Update of **MalaRis**

- Title: The impact of climate change on malaria risk
- HTML based
- archive (figures of malaria studies)
- WHO & public health authorities



<http://www.impetus.uni-koeln.de/malaris>



MalaRis

The impact of climate change
on Malaria Risk in Africa



MalaRis

Abstract

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Malaria archive

Malaria models

Scenarios

Data input

LMN

MSM

Simulations

1960-2000

LMN MSM

2001-2050

LMN MSM

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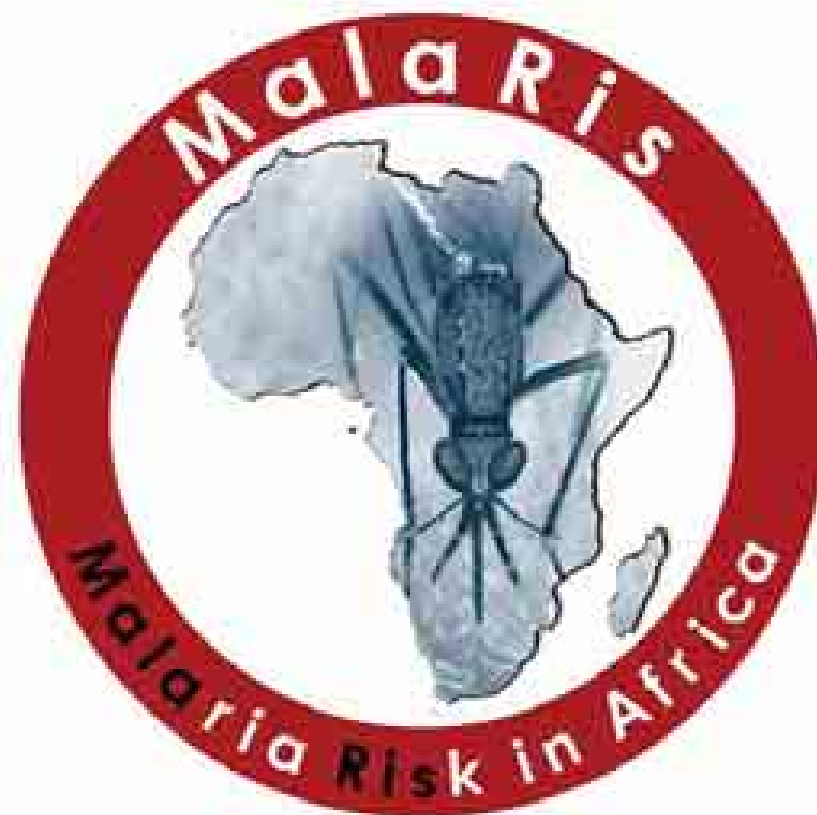
Disclaimer



MalaRis - Information System -

The impact of climate change on Malaria Risk in Africa

The simulation of the spread of malaria in Africa by the Liverpool Malaria Model enables the malaria risk assessment during the observed and projected climate change.



Malaria Archive



MalariaRis

The impact of climate change on Malaria Risk in Africa



MalariaRis

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2001-2050

LMM

MSM




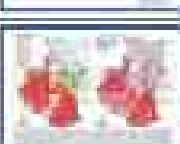
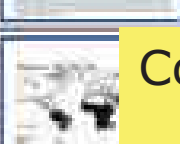

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Spatial distribution

figure, table	reference	variable	location	area	position	period (YYY1M1-YYY2M2)	mosquito species	note
	Bild Der Wissenschaft 2006 (fig. 1)	malaria risk	world	-	-	-	-	-
	Craig et al. 1999 (fig. 1)	climatic suitability of transmission	Africa	-	-	-	-	MDM results
	Craig et al. 1999 (fig. 2)	climatic suitability of transmission, expert opinion map	southern Africa	-	-	-	-	MDM results
	Craig et al. 1999 (fig. 3)	climatic suitability of transmission, expert opinion map	Kenya, Tanzania	-	-	-	-	MDM results
								historical development of the malaria risk in the world
		capita						malaria and economic growth

Collection of published figures and data

- numerous information with regard to malaria
- classified in different categories
- for example: spatial distribution

Scenarios



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IPCC SRES scenarios

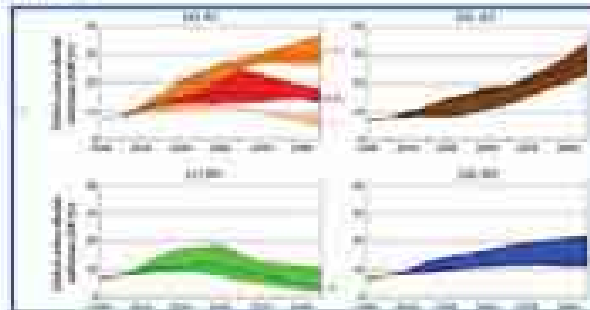
Greenhouse gases

Description of scenarios

- IPCC SRES scenarios
- stochastic changes of land use and land cover

Emission scenarios

Details with regard to the IPCC SRES (Intergovernmental Panel on Climate Change Scenario Special Report on Emission Scenarios) scenarios were published by Nakicenovic et al. (2000). Driving forces of greenhouse gases are mainly demographic and socio-economic development, as well as changes in technology and environment. Nakicenovic et al. (2000) have developed four different narrative storylines (the so-called "families" are A1, A2, B1, and B2) that try to estimate the future evolution of greenhouse gases. Six scenario groups were drawn from the four families. One group each in A2, B1, and B2, as well as three groups within A1, which are characterised by different energy technology developments: A1FI is a fossil fuel (including coal, oil, and gas) intensive, A1B is a balanced energy supply mix, and A1T is a predominantly non-fossil fuel scenario. At the expense of carbon option most of the scenarios, in particular B1 and to some extent also A1B follow a trend toward increases of renewable and nuclear energies in the long term. Note, there is no "central", "best guess" or "business-as-usual" scenario included and probabilities of occurrence are not assigned to individual SRES scenarios.



Malaria projections



Malaria

The impact of climate change
on Malaria Risk in Africa



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 - MIEM
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 - MIEM
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- Glossary
- Disclaimer

Malaria projections for 2001 to 2050

LMM projections

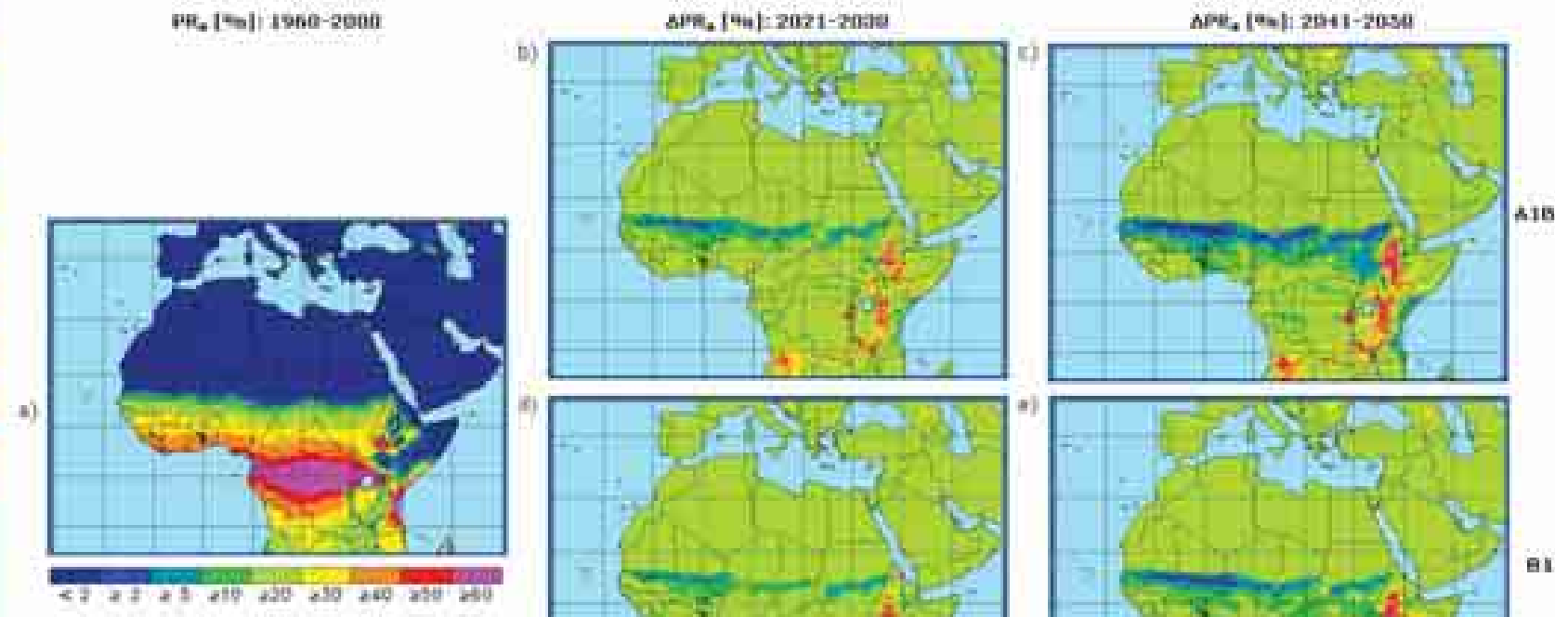
Ensemble runs for the malaria scenarios were performed by the LMM on a 0.5° grid for 2001 to 2050. The malaria model was forced by high resolution data from the reanalysis of the European Centre for Medium-Range Weather Forecasts (ECMWF) for the period 1979-2000 and the A1B scenario for the period 2001-2050.

Description of malaria projections (2001-2050)

- changes in malaria prevalence
- assessment of future epidemic risk

Ma
Sim
fro

of the Sahelian and Sudanian zone, i.e. most pronounced during the decade 2041 to 2050 (Fig. 1c). By contrast due to higher temperatures and nearly unchanged precipitation amounts the malaria prevalence increase in East Africa, in particular in highland areas (cp. Unluvar and Mertens 1998).





Thank you for your attention!

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<http://www.impetus.uni-koeln.de/malaris>

