# *Quantifying Weather and Climate Impacts on Health in Developing Countries (QWeCI)*


**A Seventh Framework Programme Collaborative Project (SICA)**

13 partners from 9 countries

www.liv.ac.uk/QWeCI

Grant agreement 243964

## The impact of climate change on malaria distribution in Africa: a multi-model approach

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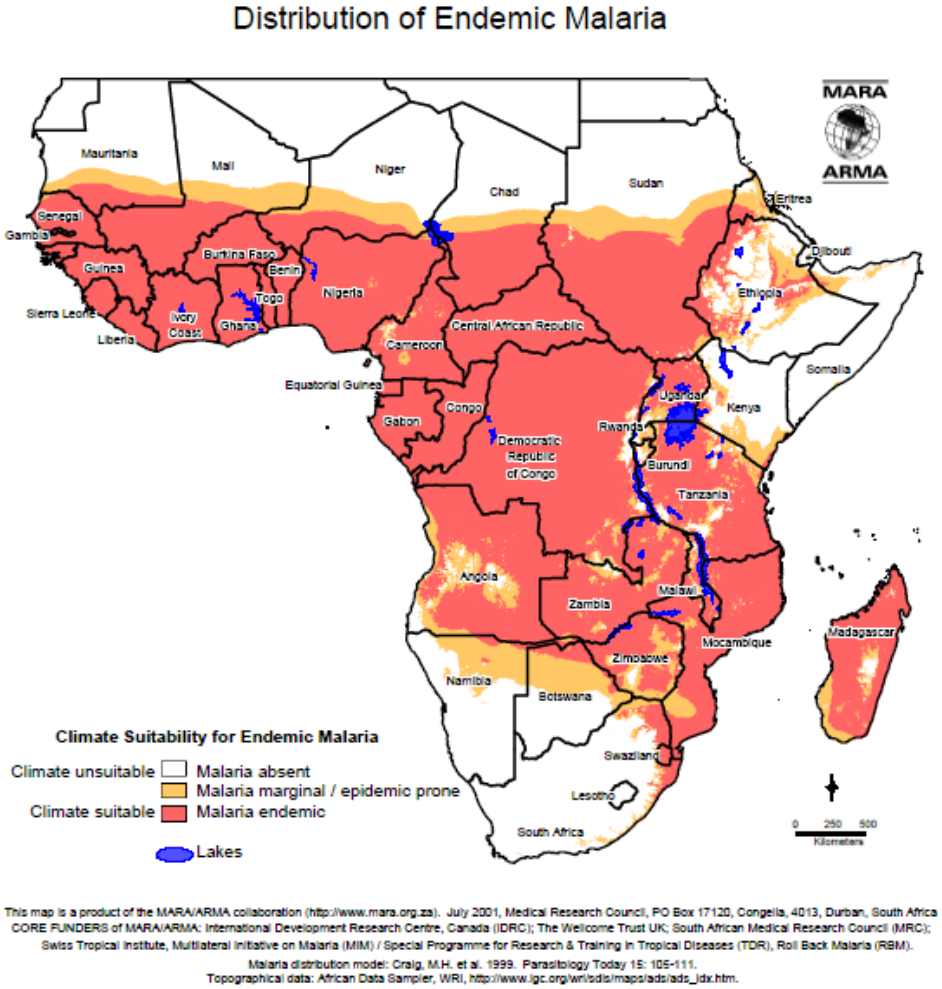
# Introduction

- Malaria caused by *plasmodium* parasite, *anopheles* mosquito vector.
- Complex relationship between climate variables (**temperature** and **rainfall**) and malaria transmission.
- Epidemic-prone areas defined where climate is marginally suitable for transmission.
- Here focus only on climate-related risk, **in reality other factors involved.**
- Impact of climate change on malaria distribution: from AR4 to AR5 – ISI-MIP project



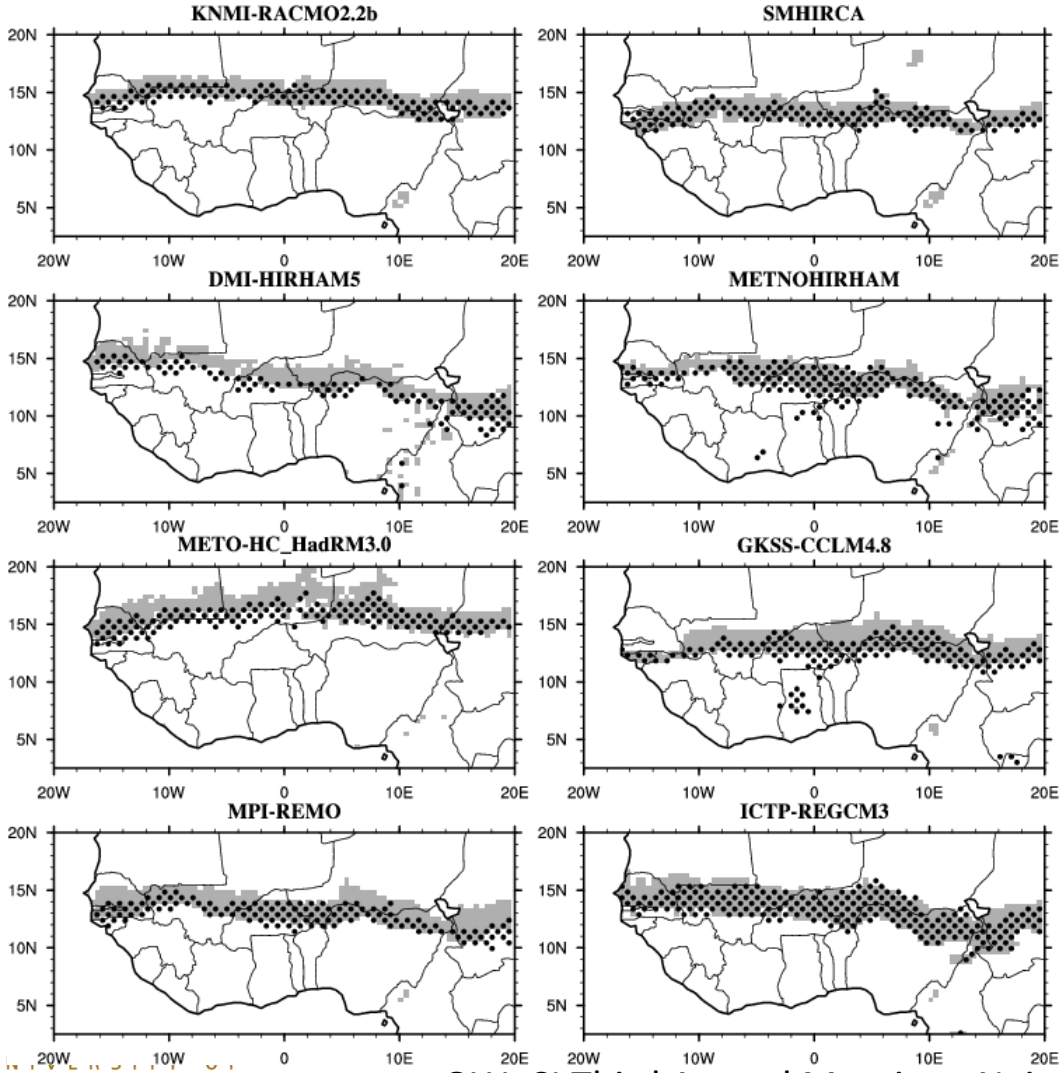

MARA malaria map www.mara.org.za

# IPCC AR4 WGII

**Human health, already compromised by a range of factors, could be further negatively impacted by climate change and climate variability, e.g., malaria in southern Africa and the East African highlands (high confidence).**

It is likely that climate change will alter the ecology of some disease vectors in Africa, and consequently the spatial and temporal transmission of such diseases. Most assessments of health have concentrated on malaria and there are still debates on the attribution of malaria resurgence in some African areas. The need exists to examine the vulnerabilities and impacts of future climate change on other infectious diseases such as dengue fever, meningitis and cholera, among others. [9.2.1.2, 9.4.3 9.5.1]

# Former climate-malaria modelling studies 1/2




*Grey: Location of the epidemic belt 1990-2010*

*Black dots: Future location of the epidemic belt 2030-2050*

*The epidemic belt location is defined by the coefficient of variation, namely:*

*Mean Incidence > 1%*
*1stddev > 50% of the average*

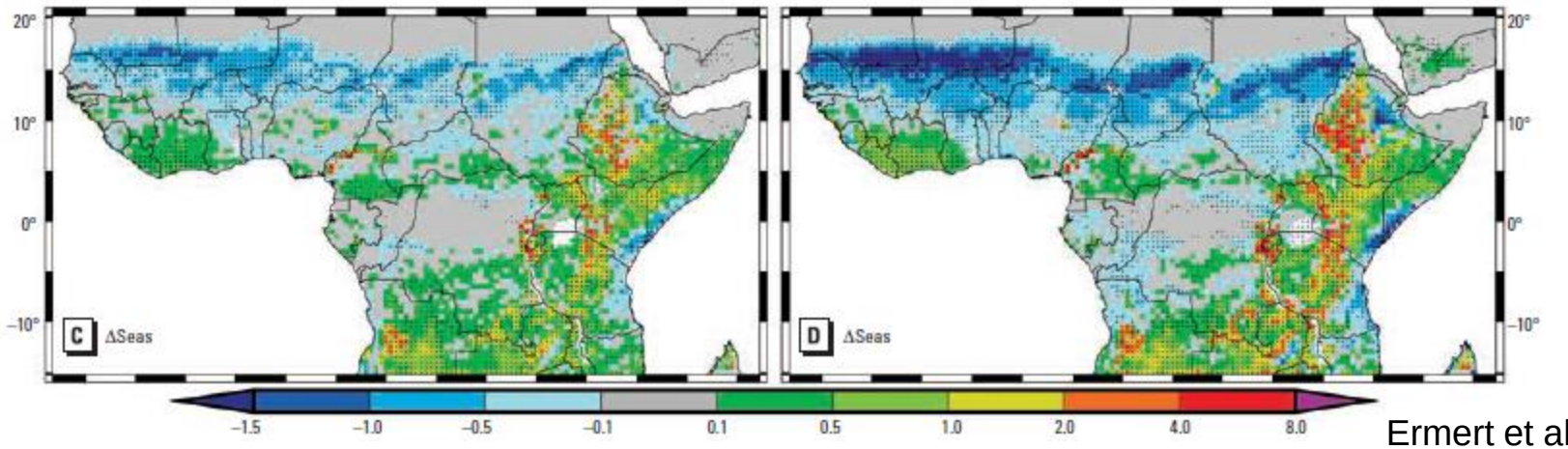
*Southward shift of the epidemic belt over WA*

*-> to more populated areas...*

Caminade et al., 2011

# Former climate-malaria modelling studies 2/2

**2021-2030** **2041-2050**




Ermert et al., 2012

Changes in the simulated length of the malaria transmission season (LMM2010 driven by the REMO RCM).

-> Shortening of the transmission season over the sahelian fringe
-> Increase over high altitude regions in eastern Africa (Somalia, Kenya

# Climate is an important factor BUT....

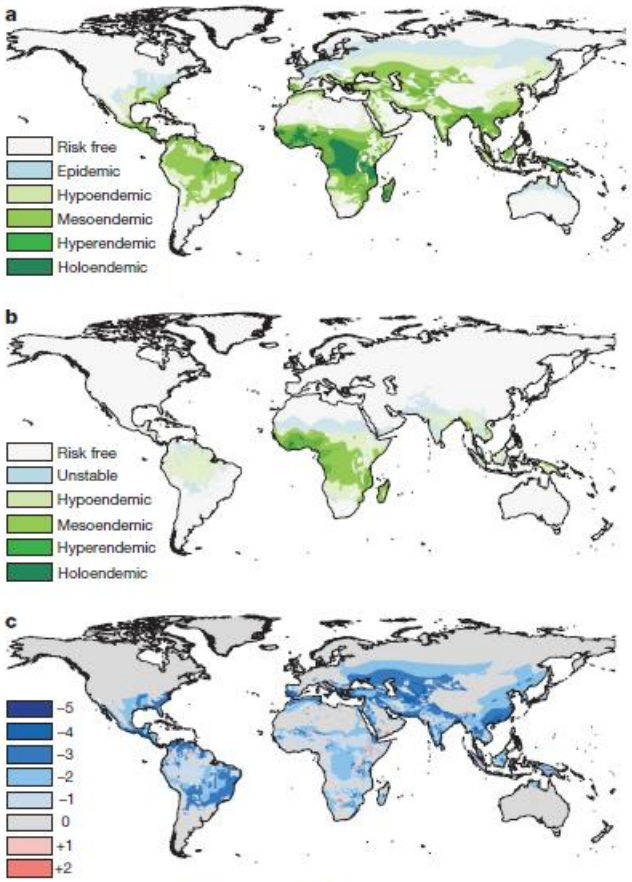



**Figure 1 | Changing global malaria endemicity since 1900.** **a**, Pre-intervention endemicity (approximately 1900) as defined in ref. 13. **b**, Contemporary endemicity for 2007 based on a recent global project to define the limits and intensity of current *P. falciparum* transmission[8]. **c**, Change in endemicity class between 1900 and 2007. Negative values denote a reduction in endemicity, positive values an increase.

1900s

2000s

2000s vs 1900s

Increase in global temperature but global decline in malaria endemicity due to intervention (Gething et al., 2010).

# IPCC AR4 WGII?

**P Reiter's:**

Nevertheless, the most catastrophic epidemic on record anywhere in the world occurred in the Soviet Union in the 1920s, with a peak incidence of 13 million cases per year, and
600,000 deaths. Transmission was high in many parts of Siberia, and there were 30,000 cases and 10,000 deaths in Archangel, close to the Arctic circle. The disease persisted in many parts of Europe until the advent of DDT. Clearly, temperature was not a limiting factor in its distribution or prevalence.

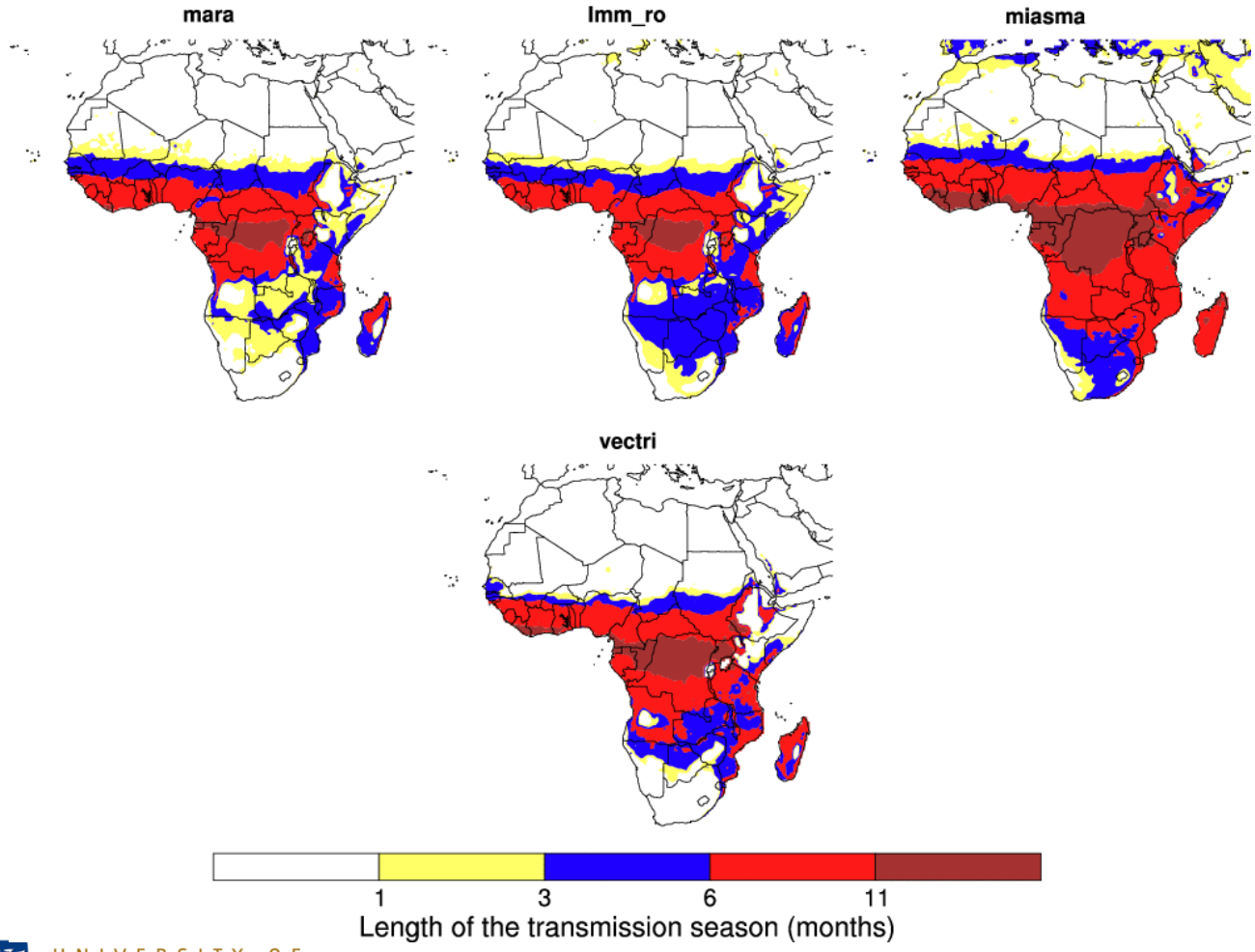
# The ISI-MIP project

**ISI-MIP Inter-Sectoral Impact Model Intercomparison**.

*Aim: Using an ensemble of climate model simulations, scenarios and an ensemble of impact models to assess simulated future impact changes and the related uncertainties.*

- **Five malaria models** investigated: MARA, LMM_ro, Vectri, UMU & MIASMA
  - Output Variables:
    - Length of the malaria transmission season e.g. LTS (in months)
    - Malaria climatic suitability (binary 0-1). Defined if LTS >=3 months
    - Additional person/month at risk for the future.
- Bias corrected climate scenarios were available for all RCPs [2.6, 4.5, 6, 8] and the historical simulations for **5 GCMs**
  - GCM1 - HadGem2-ES
  - GCM2 - IPSL-CM5A-LR
  - GCM3 - MIROC-ESM-CHEM
  - GCM4 - GFDL-ESM2M
  - GCM5 - NorESM1-M

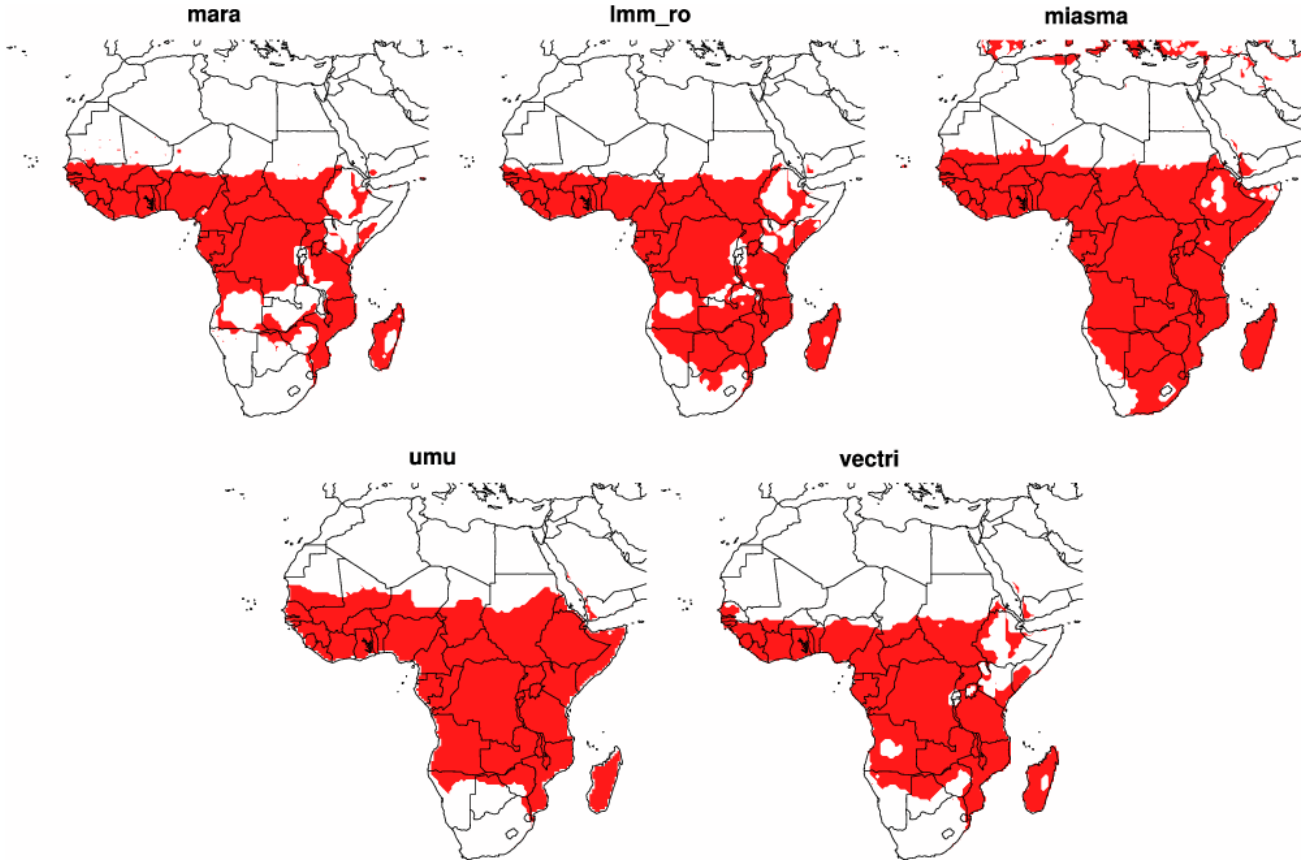
# Current climate (OBS): Length of the malaria transmission season 1999-2010




**Simulated length of the malaria transmission season** (months) for an ensemble of Malaria models.

All malaria models have been driven by observed rainfall (TRMM) and temperature (ERAINT) over the period 1999-2010.

# Current climate (OBS): Malaria climate suitability 1999-2010




**Simulated malaria climate suitability** for an ensemble of malaria models.
Red: climate is suitable for malaria
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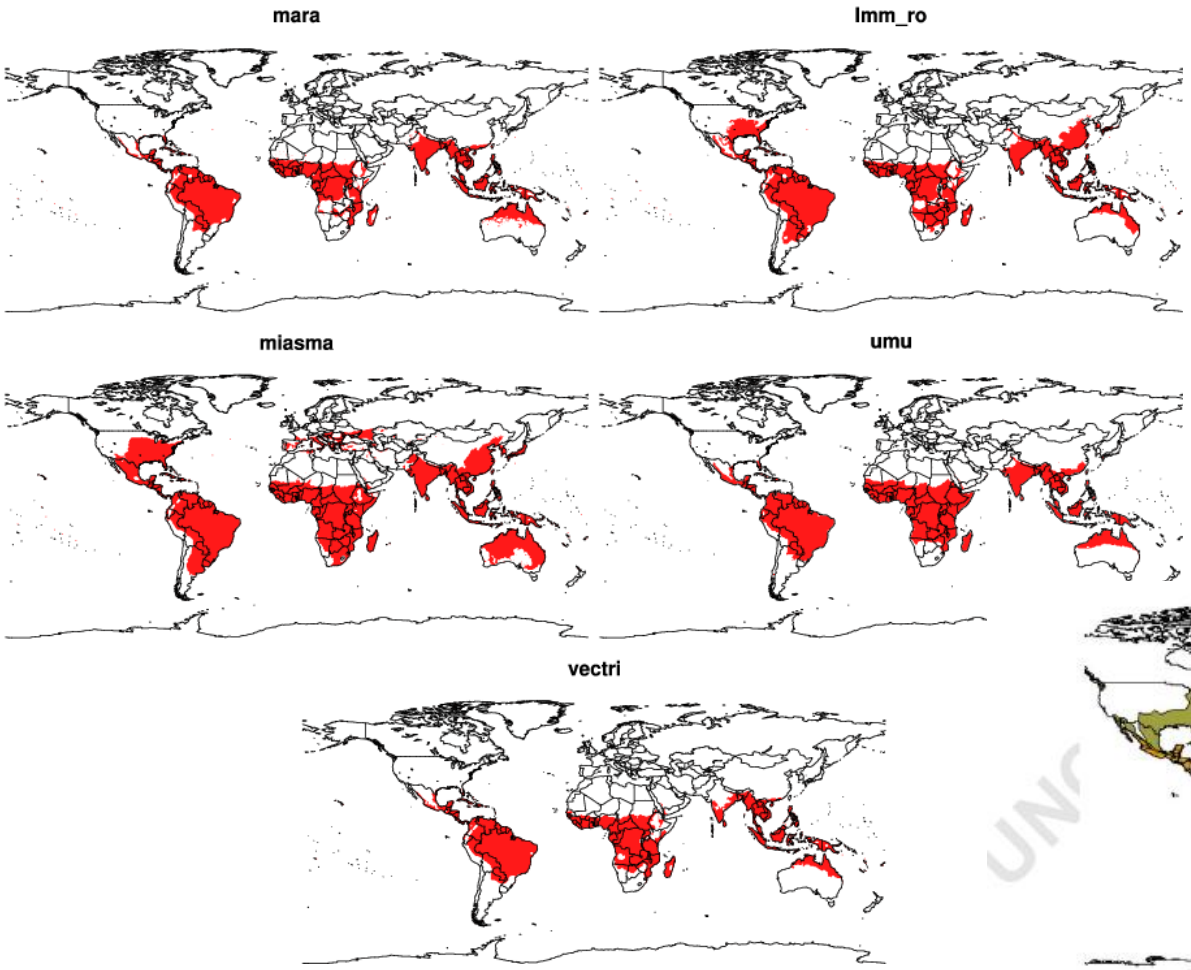


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All malaria models have been driven by observed rainfall (TRMM) and temperature (ERAINT) over the period 1999-2010.

Good agreement with WHO observations.

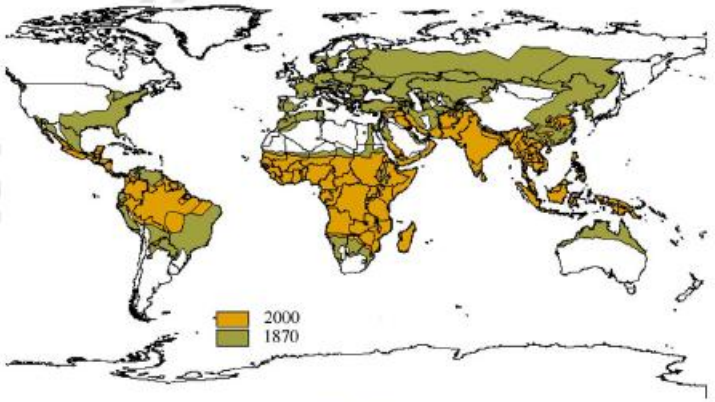
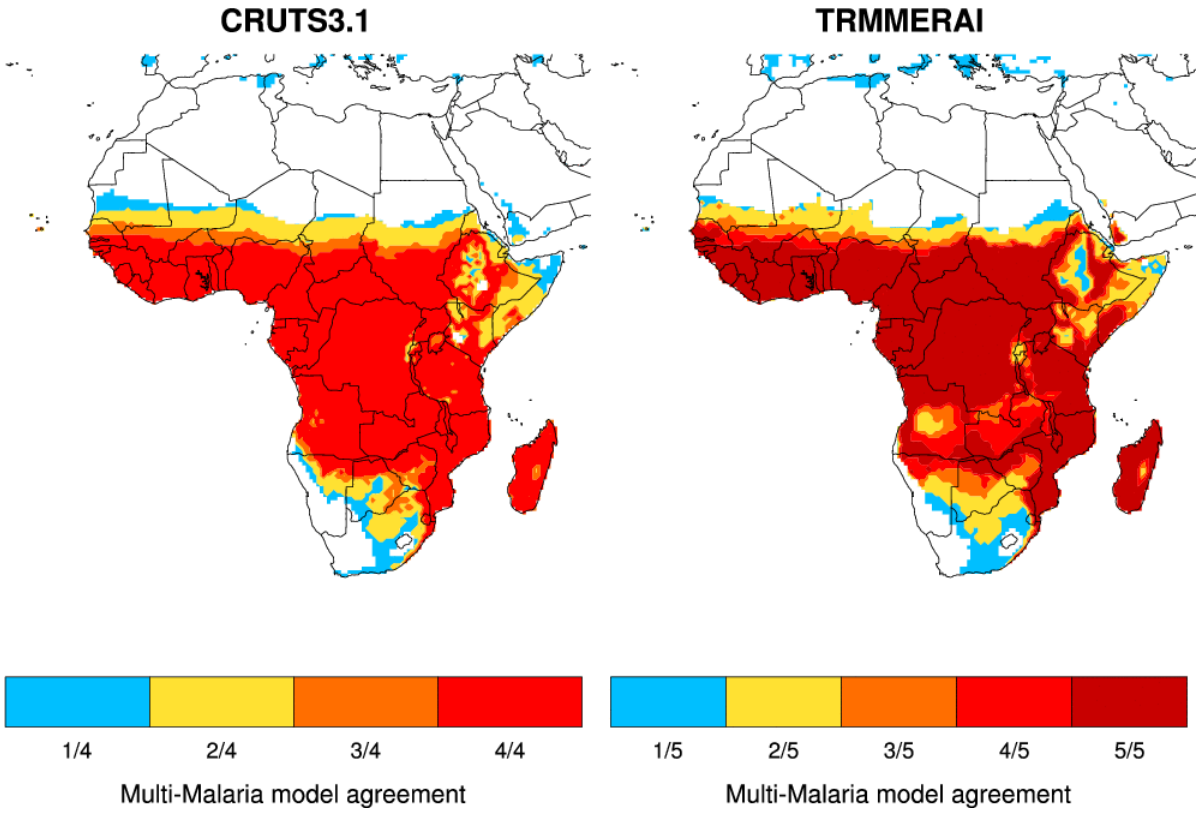



Fig. 1. Current distribution of malaria (WHO, 2001) and the historical distribution (1870).

Van Lieshout et al., 1994

# Current climate (OBS): Malaria climate suitability summary

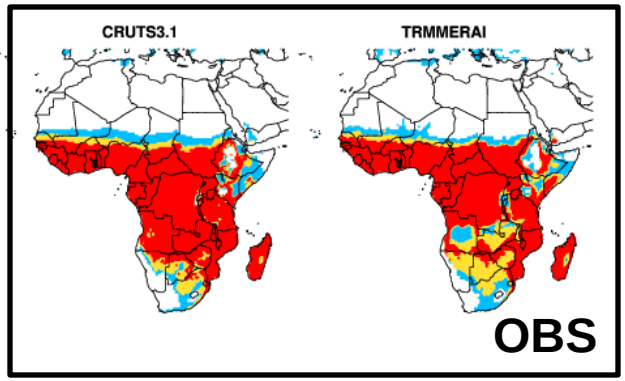


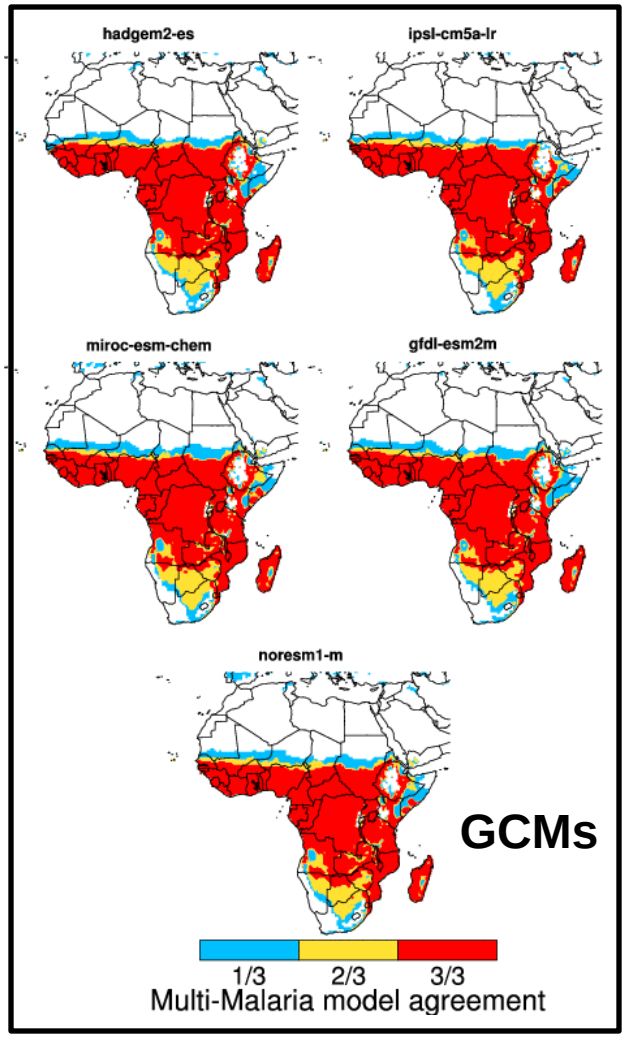

**Multi-Model Malaria model agreement.**

Left: four malaria models (Imm, umu, mara, miasma) have been driven by the CRUTS3.1 climate dataset over the period 1980-2009.

Rights: five malaria models have also been driven by observed rainfall (TRMM) and temperature (ERAINT) over the period 1999-2010.

# Current climate Validation (GCMs vs Obs)



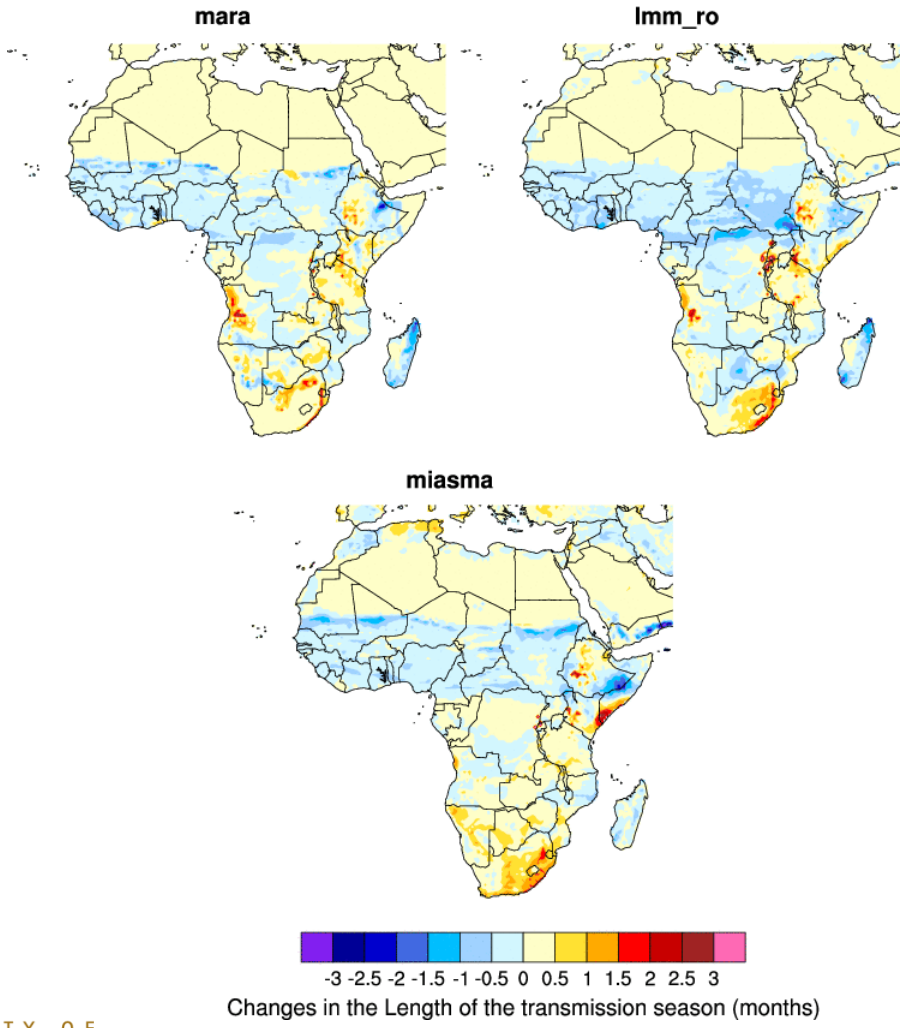




**Multi Malaria model agreement validation (obs driven vs climate model driven).**

The climate model outputs have been bias corrected before running the malaria models.

-> Good agreement between simulated malaria climate suitability driven by the GCMs and the obs.

# Recent trends: 1980-2009 vs 1901-1930



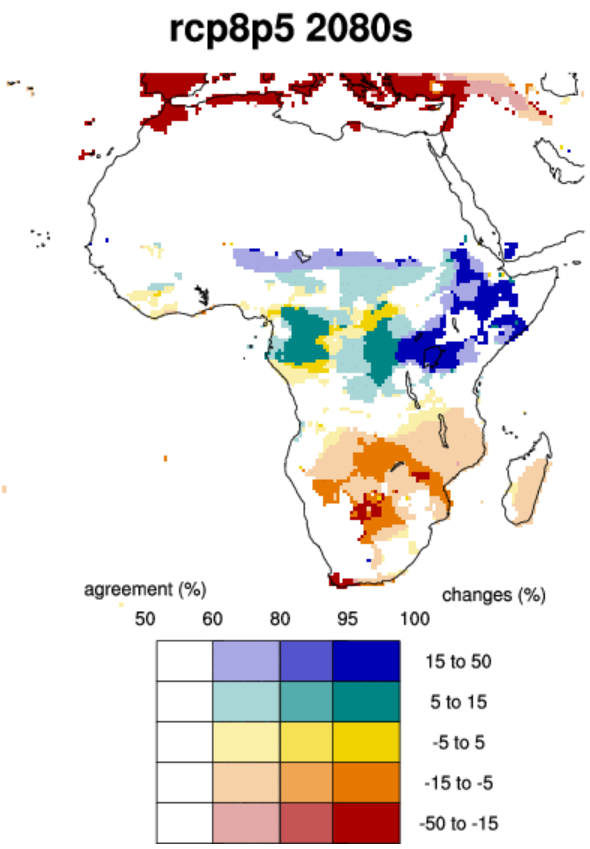

**Simulated changes in the length of the malaria transmission season** (months) 1980-2009 vs 1901-1930 for an ensemble of Malaria models.

All malaria models have been driven by observed rainfall and temperature based on the CRUTS3.1 dataset

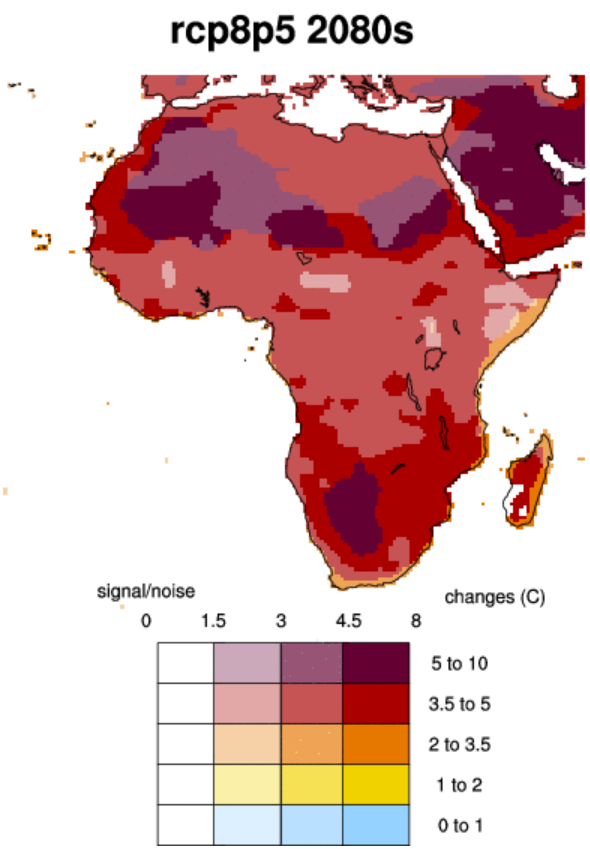
-> Increase in the length of the transmission season over the high altitude regions.
-> Slight decrease over the northern fringe of the Sahel.

# Future changes: rcp8.5 2069-99 vs 1980-2010

**Rainfall**



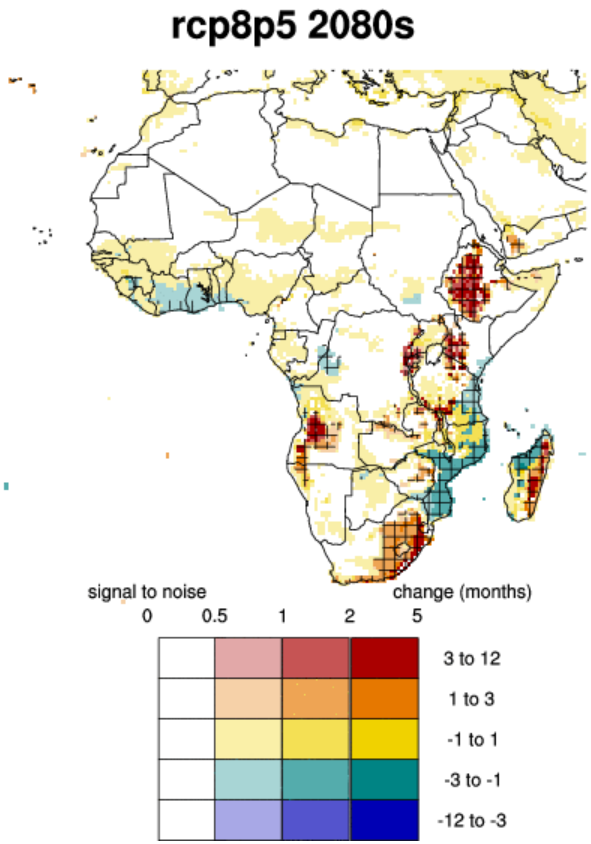

**Temperature**




Climate models agreement on:
1) the pronounced warming over the Sahara and southern Africa
2) Simulated wetter conditions over the high altitude regions over eastern Africa
3) Drying signal over southern Africa

**Derived from *Kayle et al., 2012***

# Future changes: length of the malaria transmission season rcp8.5 2069-99 vs 1980-2010



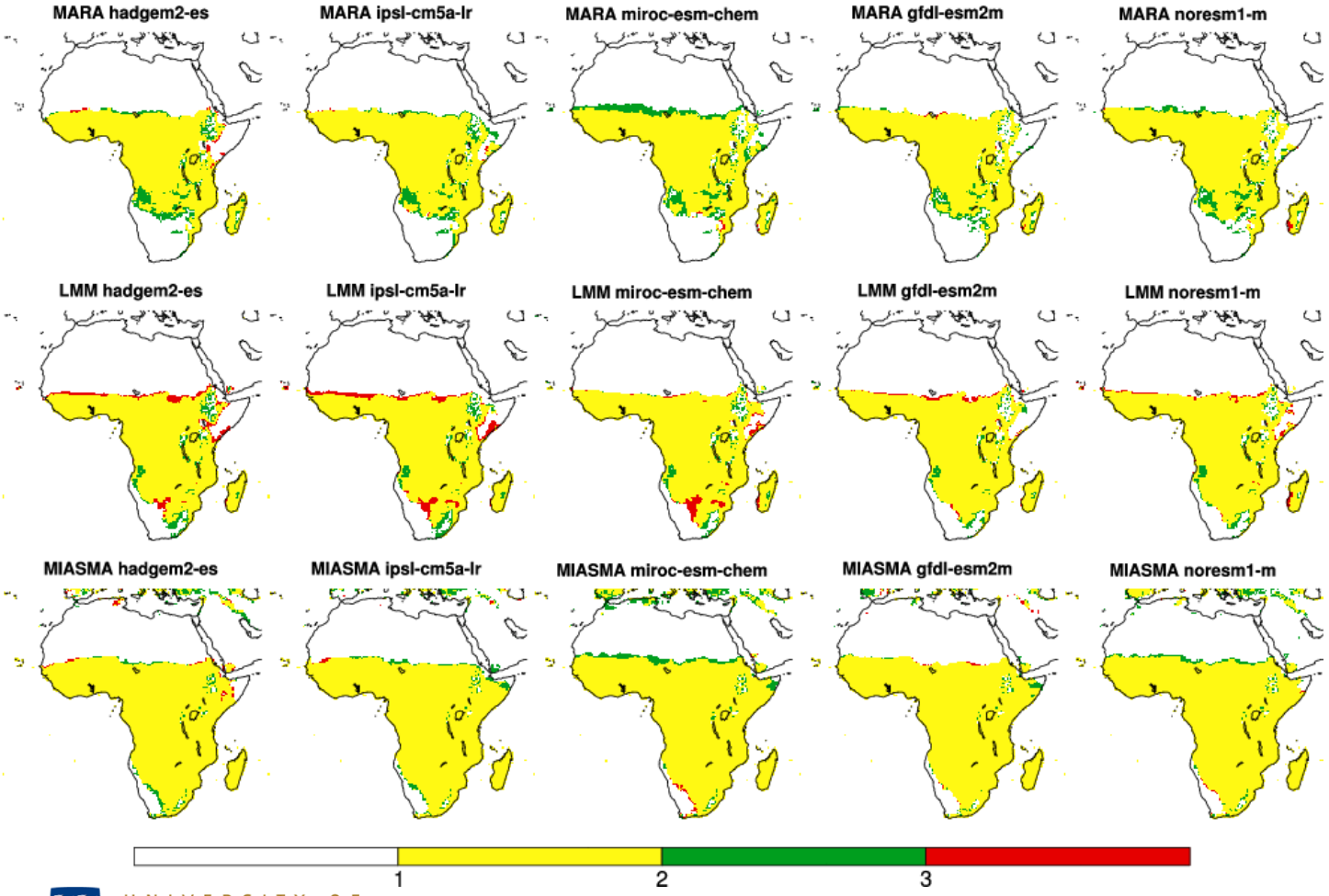

**Derived from *Kayle et al., 2012***

Climate & Malaria models agreement:

1) **Increase of the length of the transmission season over the high altitude regions** in Sudan, Kenya ,Madagascar, south Africa & Angola. For most of these regions climate becomes suitable in the future (strong temperature effect). Feature consistent across scenarios.

2) Slight decrease of the malaria season over the coasts of the Gulf of Guinea, north-western Madagascar and the eastern coasts of Tanzania and Mozambique

# Future changes: length of the malaria transmission season rcp8.5 2069-99 vs 1980-2010




Climate remains suitable for malaria transmission

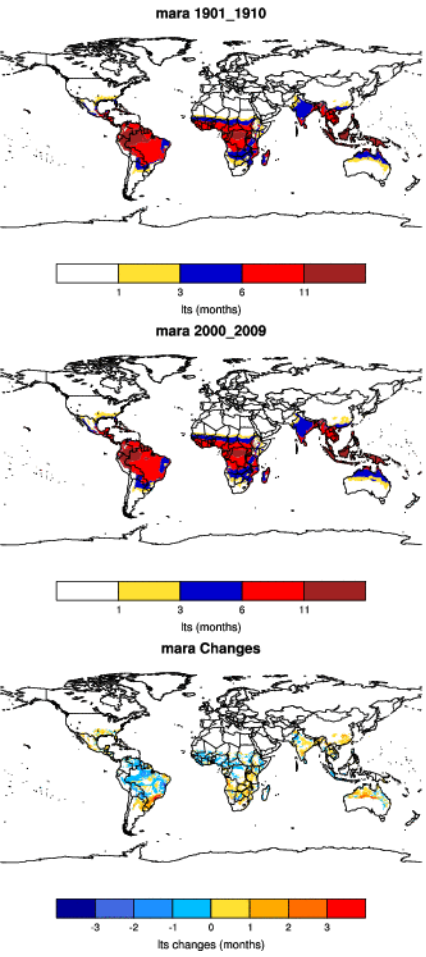
Climate becomes unsuitable

Climate becomes suitable

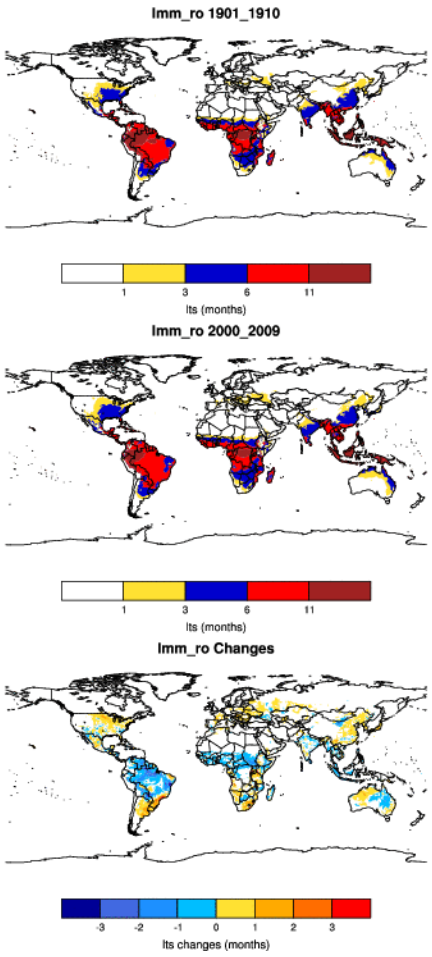
Uncertainties related to the impact model are the largest

# Climate effects on malaria distribution 2000s vs 1900s

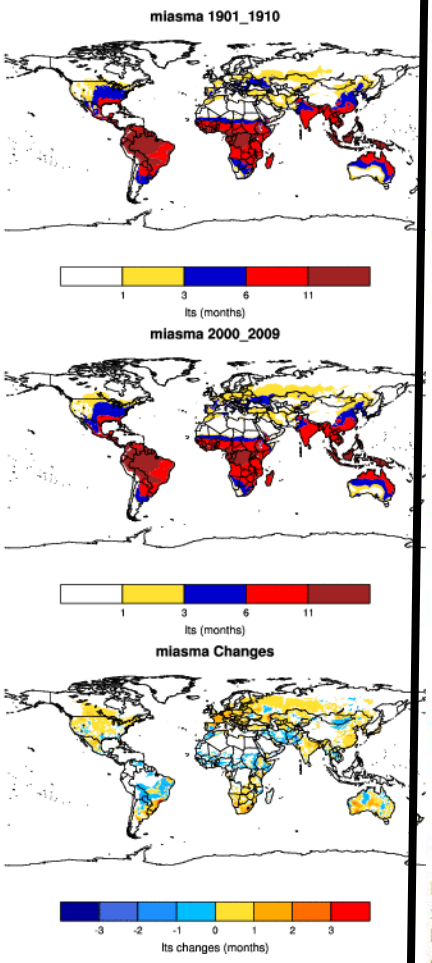
## Malaria Model 1



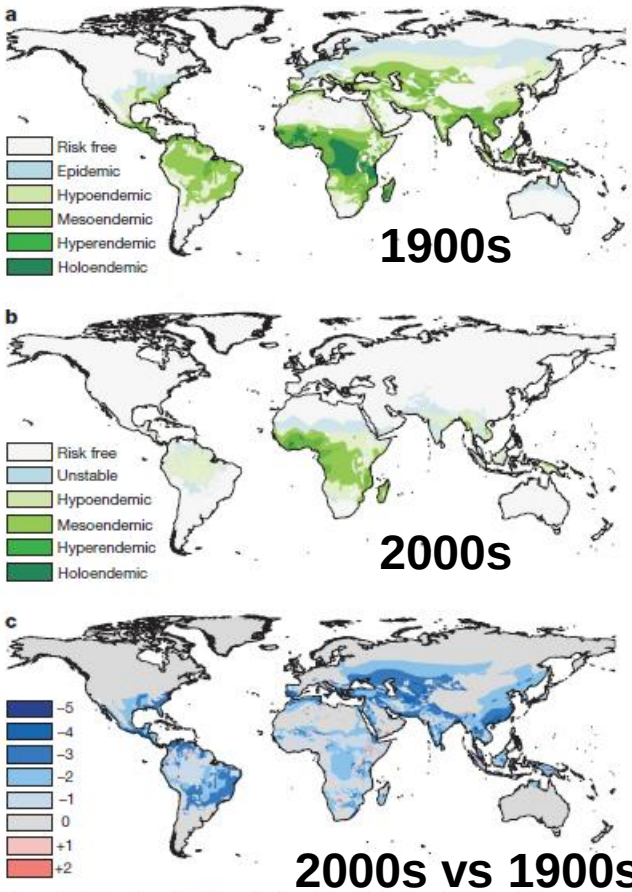

## Malaria Model 2




## Malaria Model 3




## "All effects"

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*Gething et al., 2010*

# Summary

- **Malaria transmission is very likely to increase in southern Africa and the East African highlands (high confidence).**

- The simulated decrease of the malaria season over the Sahel and the southward shift of the malaria epidemic belt over the Sahel seems to be a consistent feature **for the LMM**!

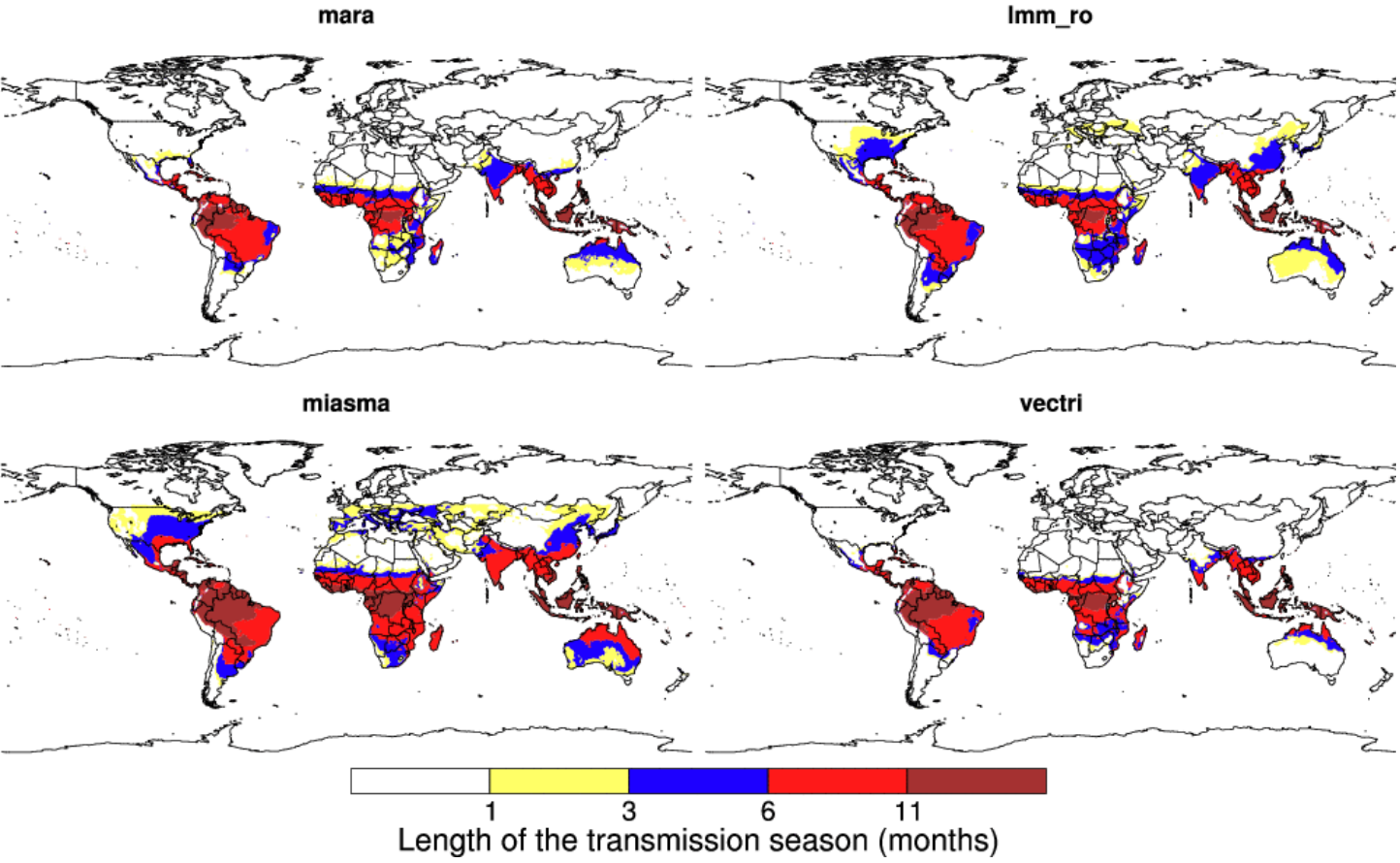
- Climate factors versus Intervention – India vs Africa

- **Perspectives:**

  Analysis for the targeted African countries -> publication plan

# Extra slides

# Current climate (OBS): Length of the malaria transmission season 1999-2010




**Simulated length of the malaria transmission season** (months) for an ensemble of Malaria models.

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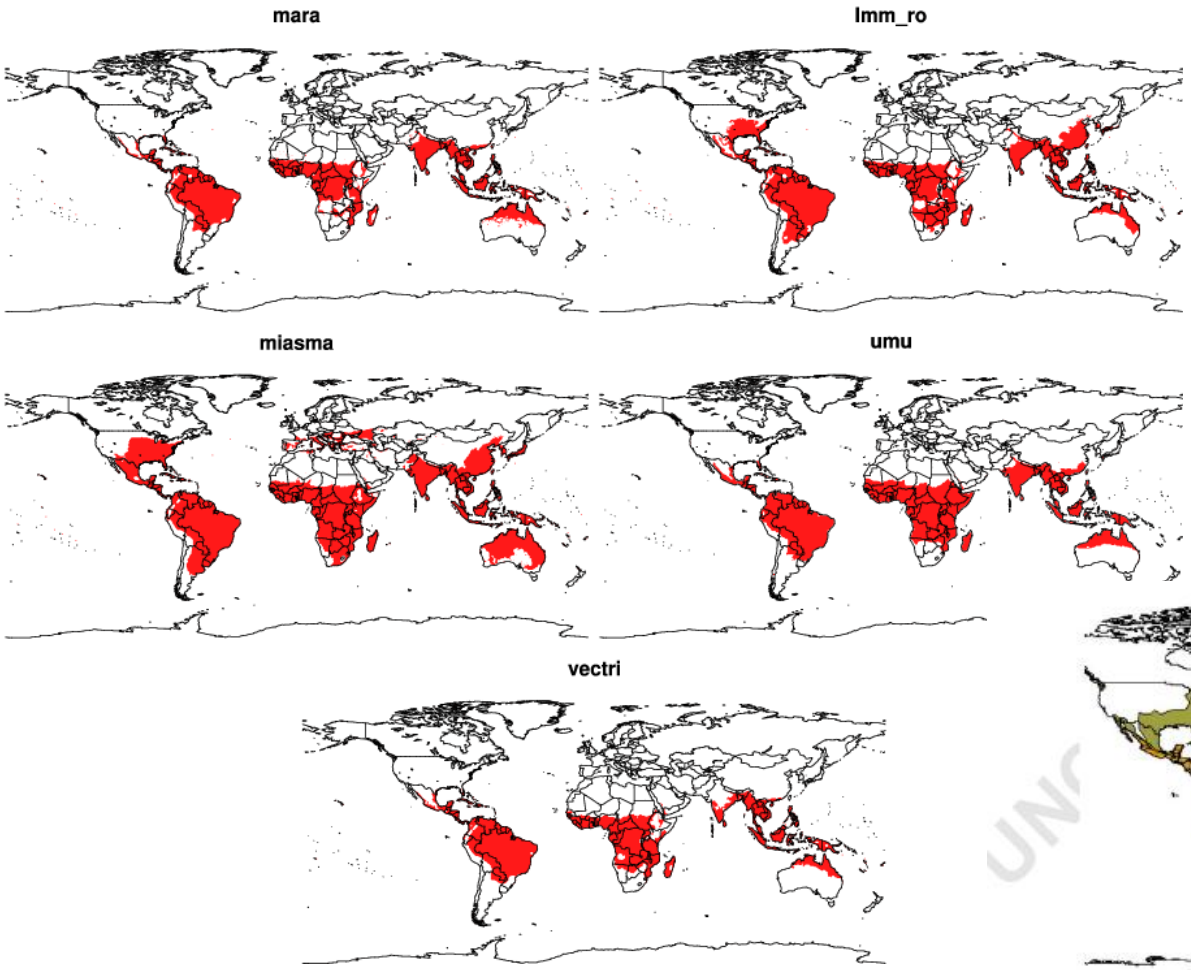
# Current climate (OBS): Malaria climate suitability 1999-2010

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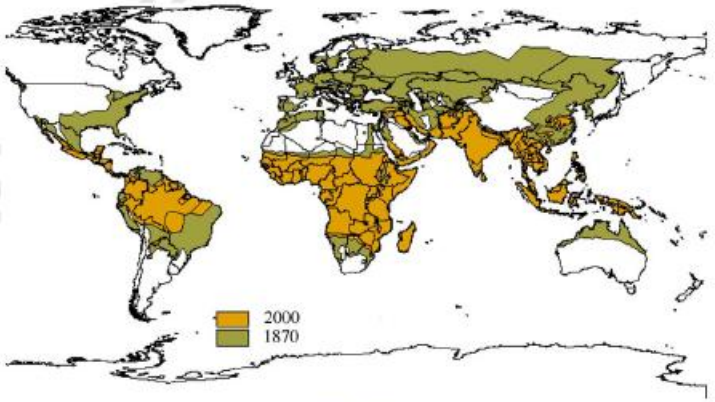


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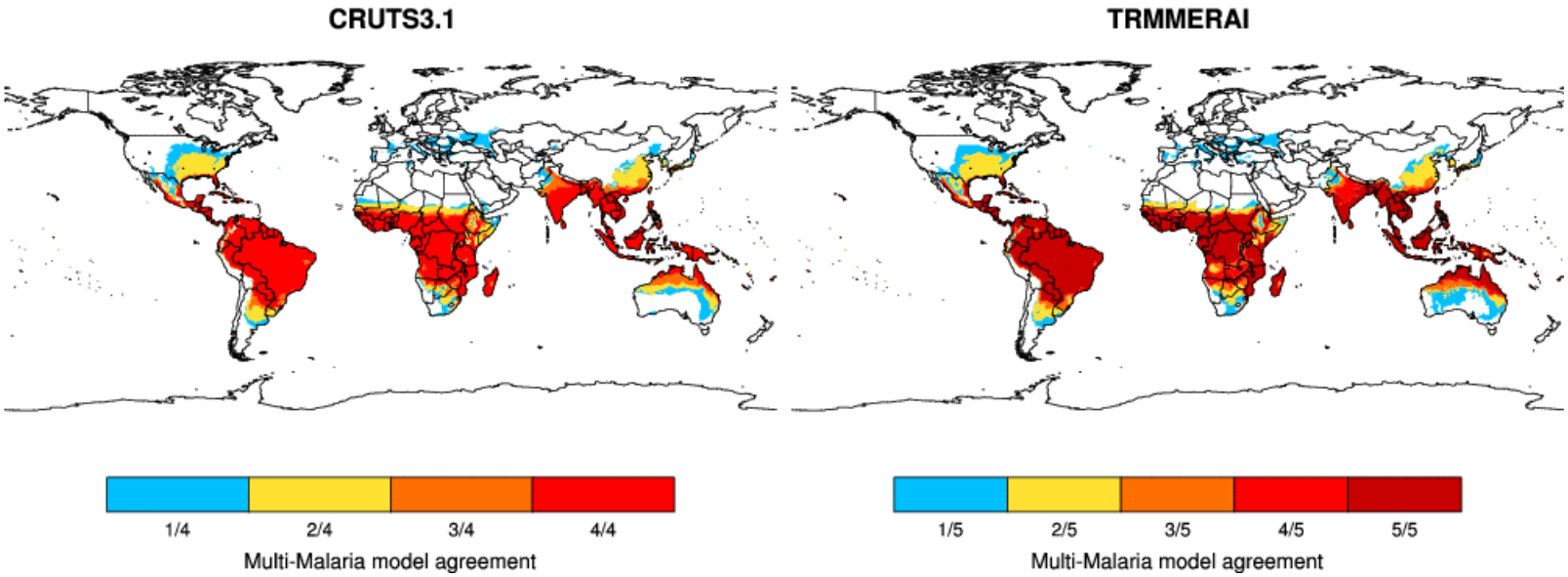


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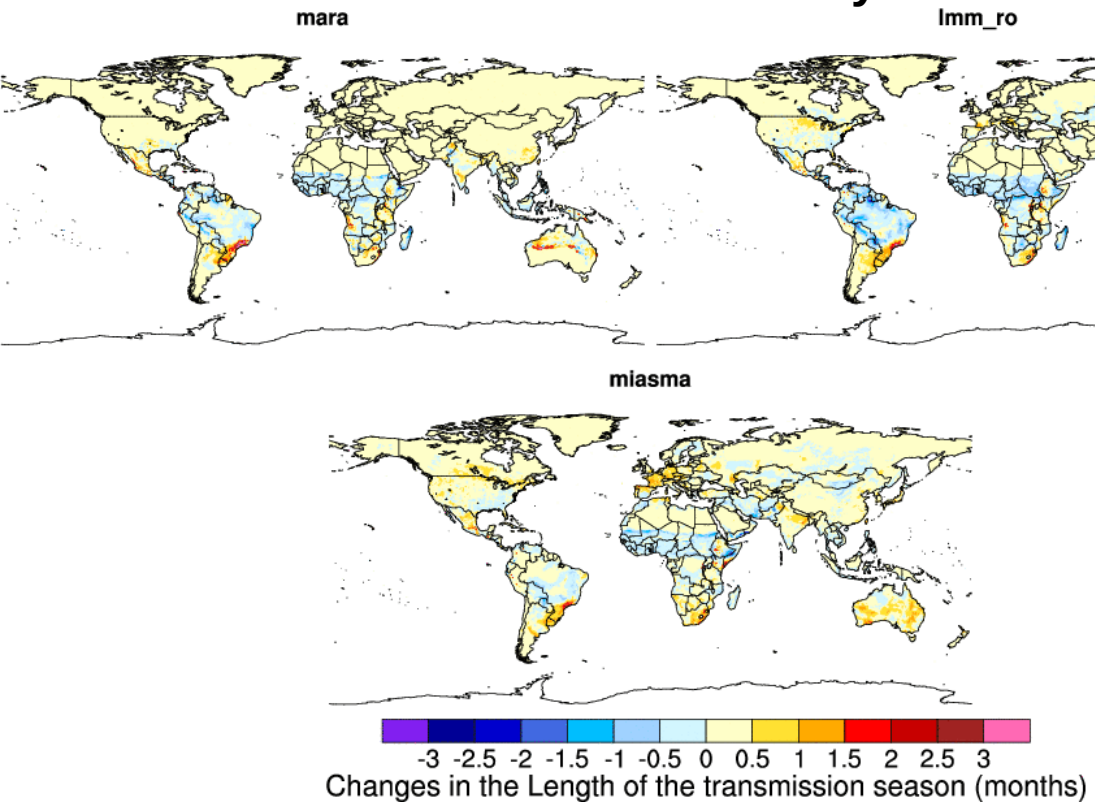
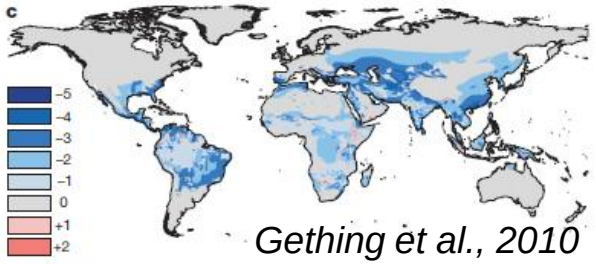
# Recent trends: 1980-2009 vs 1901-1930

## Climate effect only




## All effects



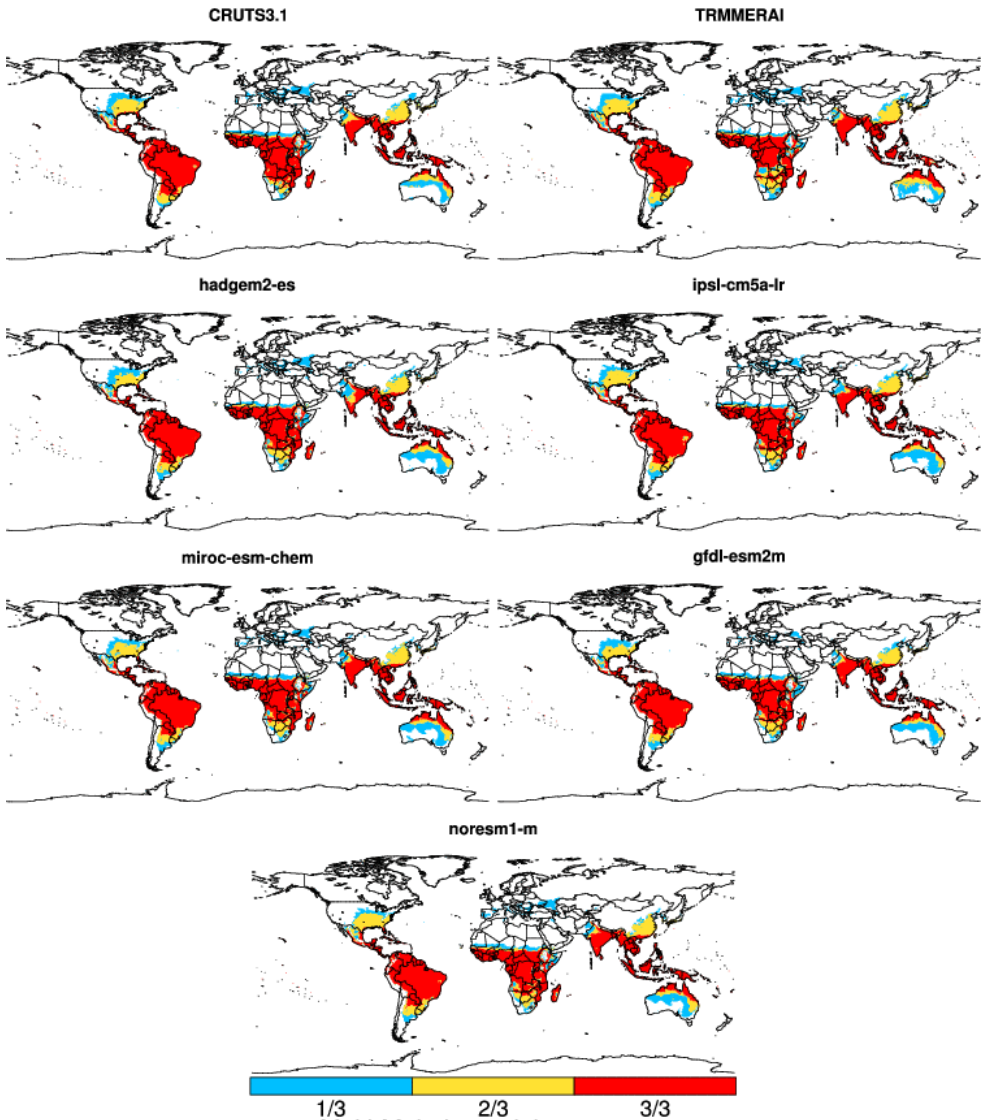

*Gething et al., 2010*

**Figure 1 | Changing global malaria endemicity since 1900.** **a**, Pre-intervention endemicity (approximately 1900) as defined in ref. 13. **b**, Contemporary endemicity for 2007 based on a recent global project to define the limits and intensity of current *P. falciparum* transmission[8]. **c**, Change in endemicity class between 1900 and 2007. Negative values denote a reduction in endemicity, positive values an increase.

**Change in malaria endemicity over Africa and to less extent over south america strongly driven by climate**

**Changes in Europe, India, Asia & the US more related to malaria control measures...**

# Current climate Validation (GCMs vs Obs)




**OBS**

**GCMs**

**Multi Malaria model agreement validation (obs driven vs climate model driven).**

The climate model outputs have been bias corrected before running the malaria models.

-> Good agreement between simulated malaria climate suitability driven by the GCMs and the obs.

# Future climate: from CMIP3 to CMIP5

CMIP3

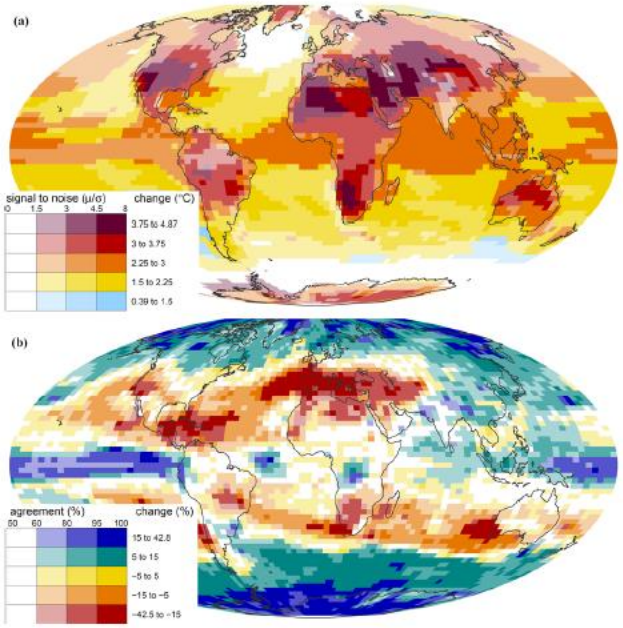
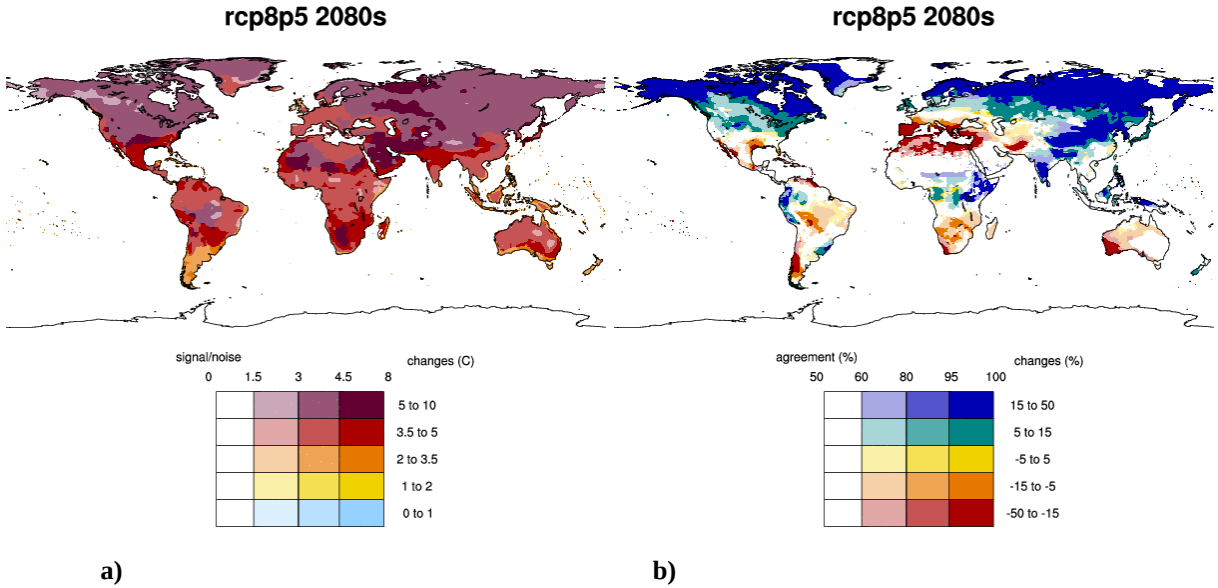



**Fig. 10.** **(a)** A synthesis of the maps shown in Fig. 6a and Fig. 6e, the different hues represent change in temperature between 1961–1990 and 2070–2099 for the mean of the IPCC AR4 ensemble based on the SRES A1B scenario, the different saturations represent signal-to-noise ($\mu/\sigma$) across the ensemble. **(b)** a synthesis of the maps shown in Fig. 6b and d, the different hues represent change in precipitation between 1961–1990 and 2070–2099 for the mean of the IPCC AR4 ensemble based on the SRES A1B scenario, the different saturations represent percentage model agreement across the ensemble.

CMIP5

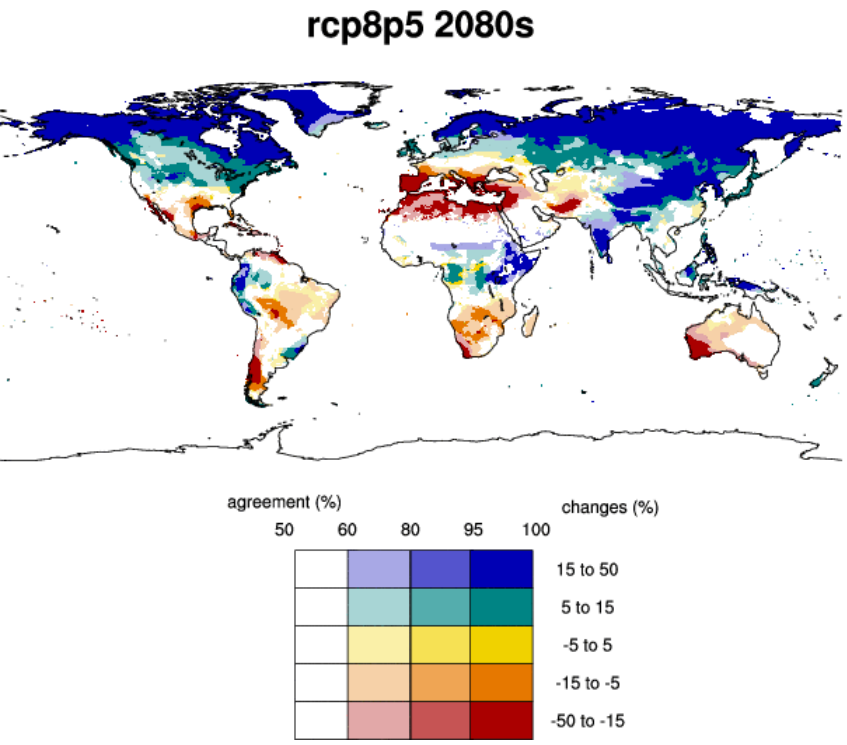



**a)** **b)**

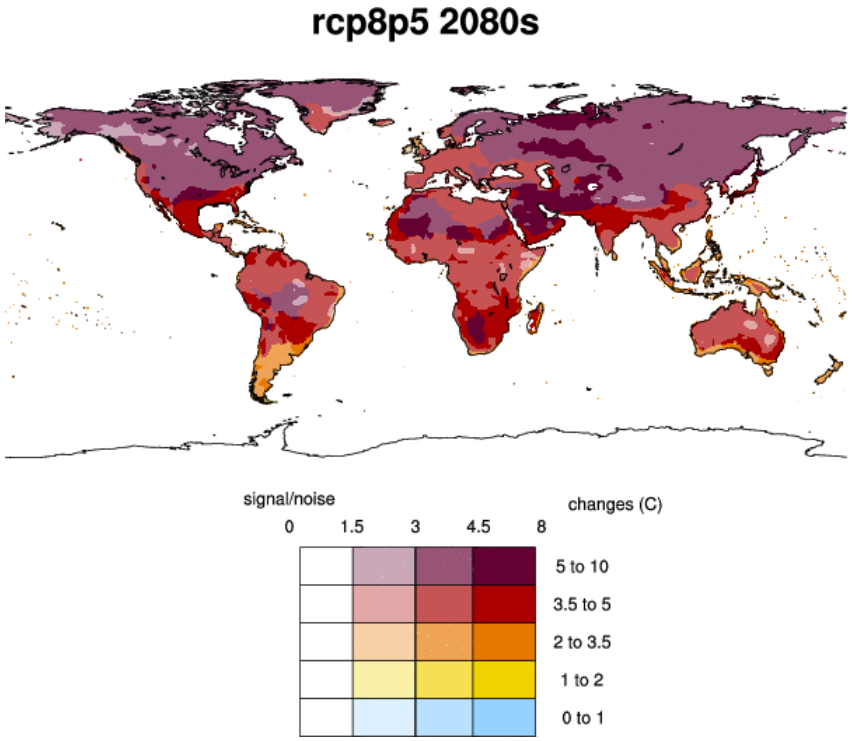
**Fig. 2S.** **(a)** The different hues represent change in annual temperature between 1980– 2010 and 2069–2099 for the mean of the IPCC AR5 ISI-MIP sub-ensemble based on the rcp8p5 scenario, the different saturations represent signal-to-noise (μ/Sigma) across the ensemble (the noise is defined as one standard deviation within the multi-model ensemble). **(b)** The different hues represent change in annual precipitation between 1980–2010 and 2069–2099 for the mean of IPCC AR5 ISI-MIP sub-ensemble based on the rcp8p5 scenario, the different saturations represent percentage model agreement across the ensemble.

# Future changes: rcp8.5 2069-99 vs 1980-2010

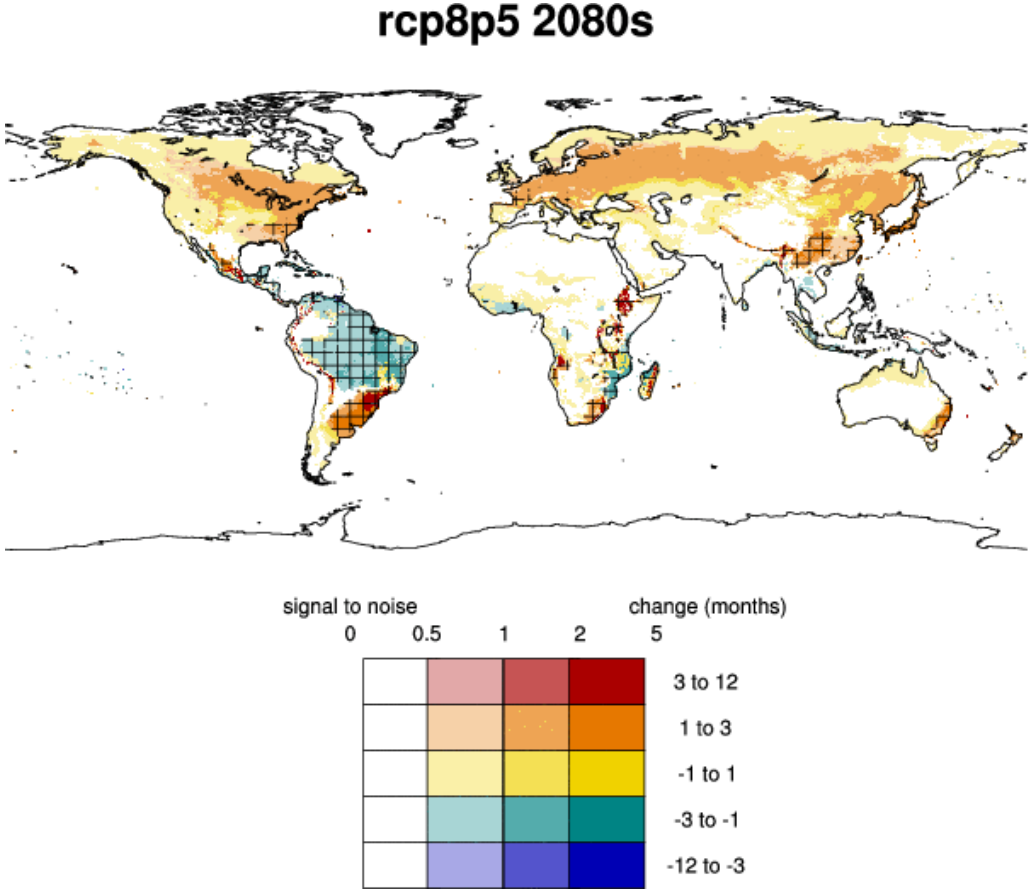
**Rainfall**




**Temperature**



# Future changes: length of the malaria transmission season rcp8.5 2069-99 vs 1980-2010

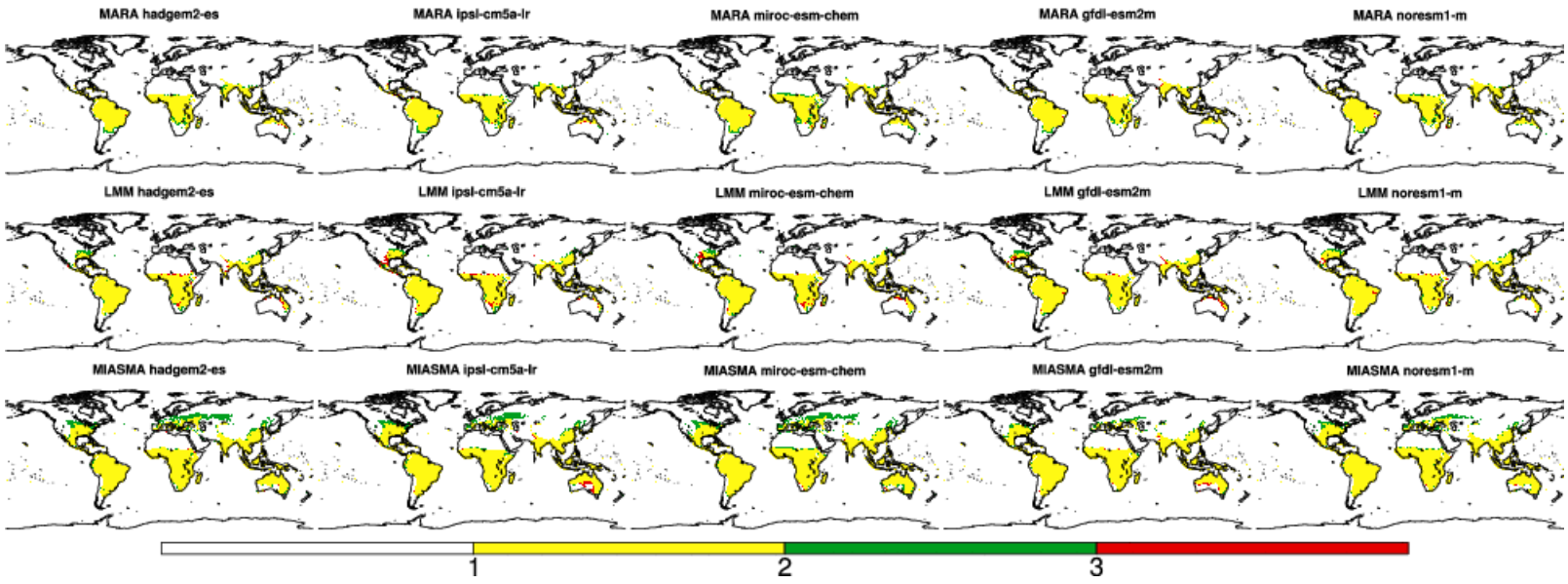



**Derived from *Kayle et al., 2012***

**Changes in simulated length of the malaria season.** The different hues represent change in the length of the transmission season between 1980– 2010 and 2069–2099 for the mean of the IPCC AR5 ISI-MIP sub-ensemble based on the rcp8p5 scenario, the different saturations represent signal-to-noise (μ/Sigma) across the ensemble (the noise is defined as one standard deviation within the multi-GCM and multi-malaria ensemble e.g 3 malaria models and 5GCMs = 15 points). The stippled area shows the multi-malaria multi GCM agreement (60% of the models).

**Increase in the length of the malaria season over medium-high altitude regions (eastern Africa, eastern Madagascar, eastern US, southern America, northern India. Temperature driven (over eastern Africa wetter and warmer conditions). Decrease over Brazil related to drier conditions**

# Future changes: length of the malaria transmission season rcp8.5 2069-99 vs 1980-2010



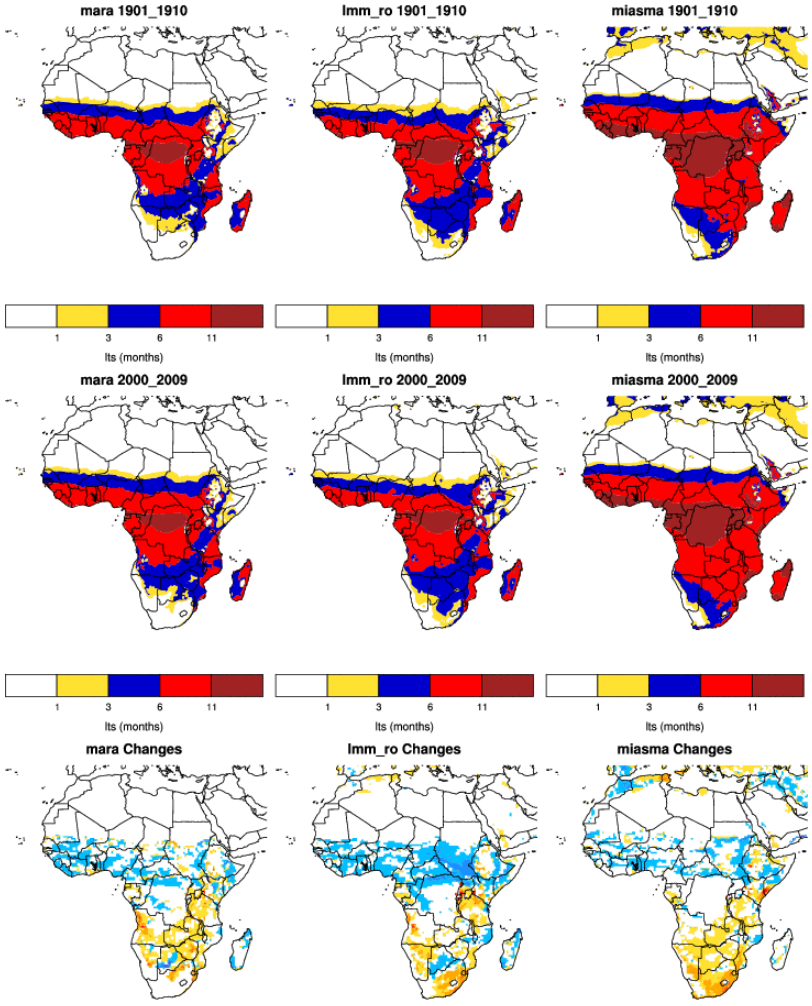

Climate remains suitable for malaria transmission
Climate becomes unsuitable
Climate becomes suitable
Uncertainties related to the impact model are the largest

# Climate effects on malaria distribution 2000s vs 1900s

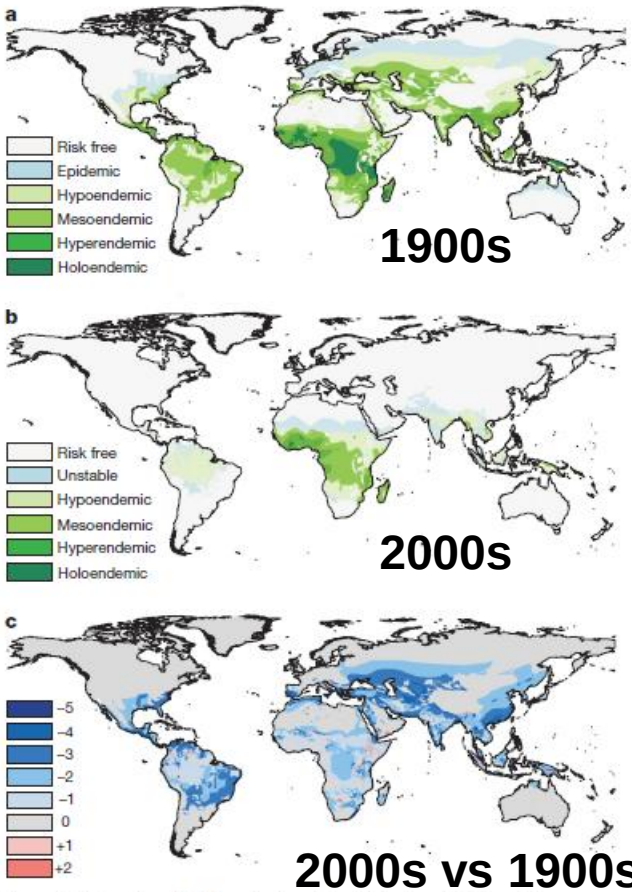
## Malaria Model 1

## Malaria Model 2

## Malaria Model 3




## "All effects"

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*Gething et al., 2010*

# Impact of climate change on malaria distribution: Lit review (few slides)

- Ermert et al (EHP paper map), Caminade et al. (ASL plot), Martens et al (plot from his old MIASMA paper)
  - xxxx
- Other studies & IPCC AR4
  - Yyyy
  - Summary

# Impact of climate change on malaria distribution: Where are we now?

- ISI-MIP protocol
- Methods (model def, variables etc)
- Results plan
  - Current climate
  - Recent trends (to do)
  - Future climate
  - Summary table (what did we know before & after QWeCI/ISI-MIP)