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

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Impact of climate change on malaria transmission in Africa: the good, the bad and the unknown

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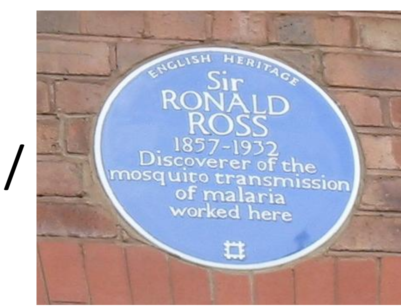
Malaria Background

- Caused by *Plasmodium spp* parasite which is transmitted by bites of the *Anopheles spp* mosquito
- WHO Global elimination program in mid-20th C was successful in Europe and USA
- Now mainly sub-Saharan Africa (*P. Falciparum*) (91%) and Asia (*P. Falciparum and P. Vivax*)
- Mainly affects children, pregnant women and elders
- Estimated 660,000 deaths worldwide in 2010
- Fallen 33% in sub-Saharan Africa since 2000 -> Roll Back Malaria Programme, Bill & Melinda Gates fundation, World Bank Malaria Booster programme...

A bit of History

- Sir Ronald Ross, Nobel Prize 1902 working in Liverpool, created the first malaria model.
- 1916 Ross published his theory of *“A priori Pathometry”* – mathematical approach to study of disease dynamics – general approach (not just malaria) -> First Ro Model formulation
- In contrast to the *a posteriori* method – fitting analytics to observed data (i.e. statistical modelling).
- Subsequently refined and extended (Lotka, 1923, Macdonald, 1957, Dietz, 1975, Aron and May 1982, Smith and McKenzie, 2004, see Smith et al., 2012 for a review)
- First multi-malaria model inter-comparison exercice -> ISI-MIP / QWeCI / Healthy Futures



ISI-MIP framework

ISI-MIP Inter-Sectoral Impact Model Intercomparison.

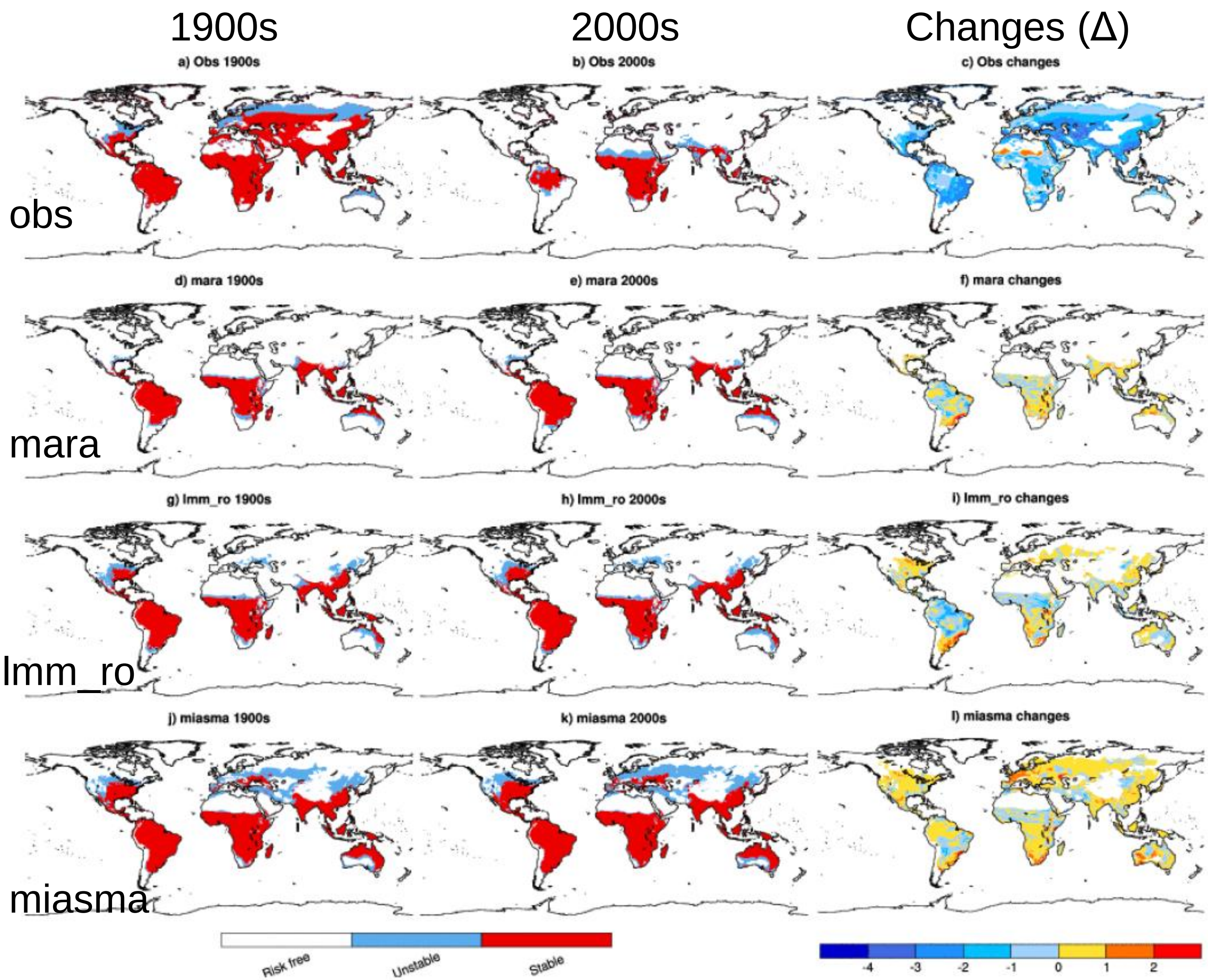
Aim: Using an ensemble of climate model simulations, scenarios and an ensemble of impact models to assess simulated future impact changes and the related uncertainties.

- **Five malaria models** investigated: MARA, LMM_ro, Vectri, Umea & 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.** Population scenario **SSP2 (UN)**
  - GCM1 - HadGem2-ES
  - GCM2 - IPSL-CM5A-LR
  - GCM3 - MIROC-ESM-CHEM
  - GCM4 - GFDL-ESM2M
  - GCM5 - NorESM1-M

Outline

- Do the malaria models reproduce the observed trends in malaria endemicity over the 20th century?
- What is the impact of climate change on malaria distribution based on a multi-model ensemble? Uncertainties?
- How do the different malaria models behave under a warmer climate?
- Conclusions

20th century trends over the globe: Simulation versus "Observation"

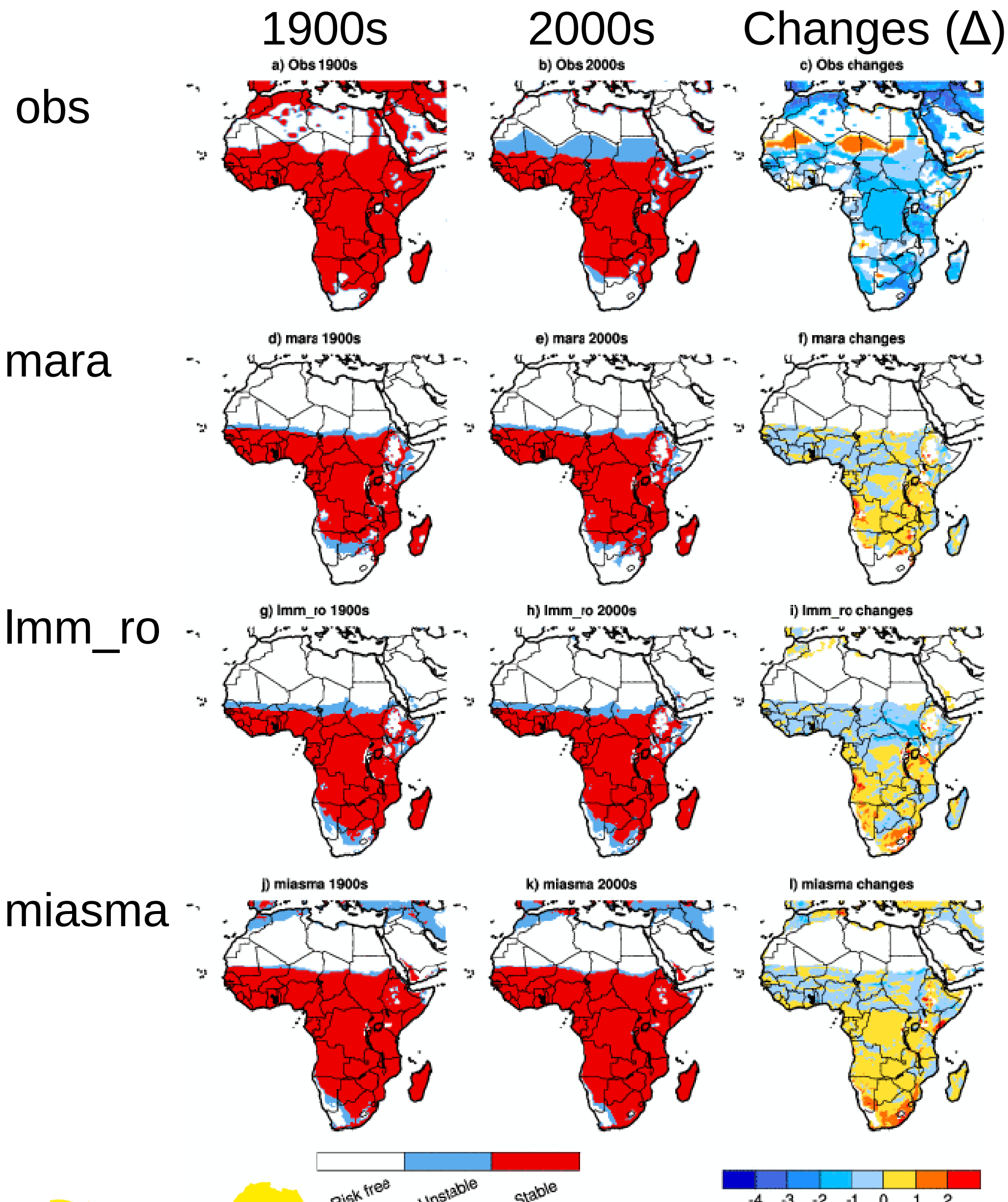


Pre-intervention (1900s): miasma is doing a good job

Post-intervention (2000s): mara provides a realistic picture at global scale

The observed decline of malaria endemicity over the 20th century at global scale more related to control measure than climate change

20th century trends over Africa: Simulation versus "Observation"



Pre-intervention (1900s): miasma is doing a good job

Post-intervention (2000s): mara provides a realistic picture over Africa

Decrease in malaria endemicity over the Sahel reproduced by the malaria models driven by climate parameters only

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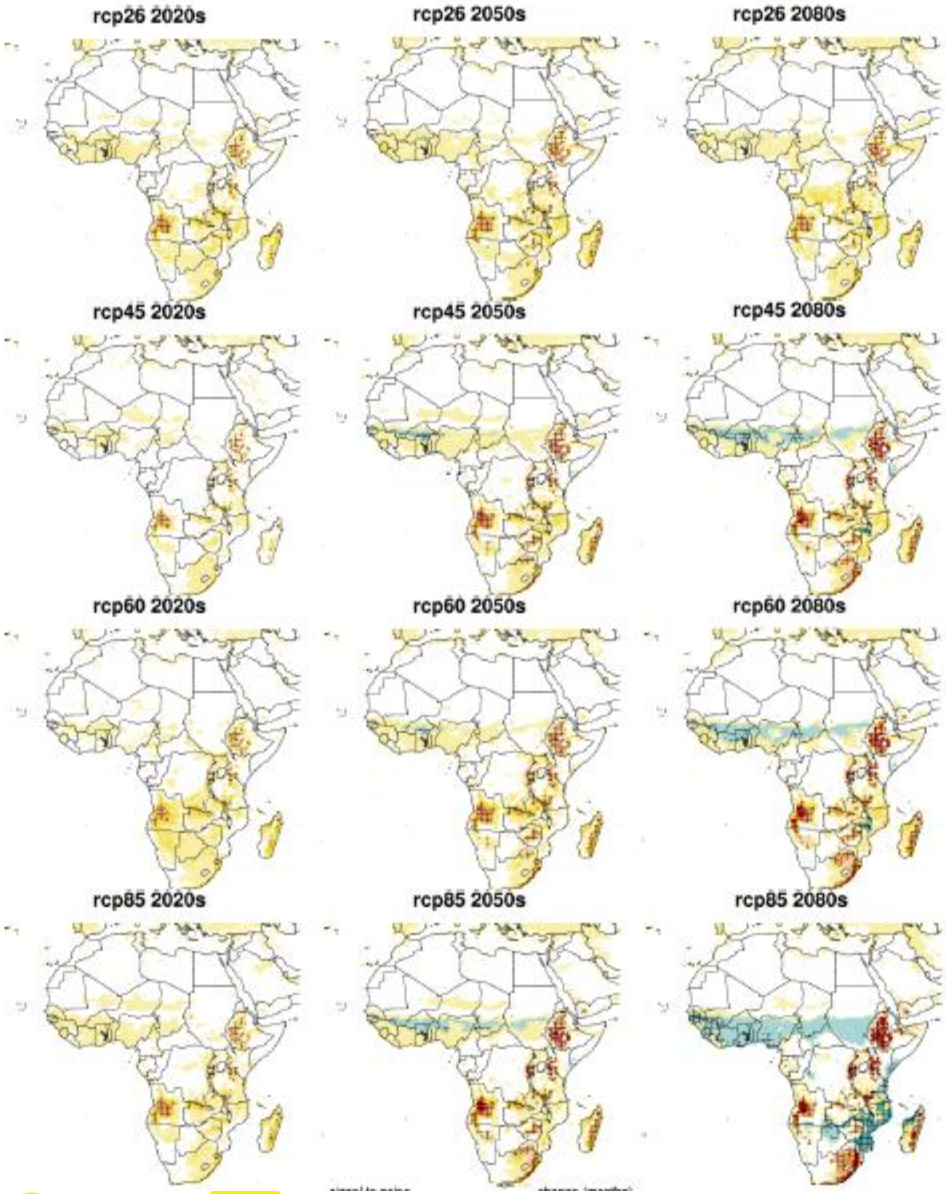
Climate may have partly contributed to the observed changes over the Sahel and the highlands (no causality!)

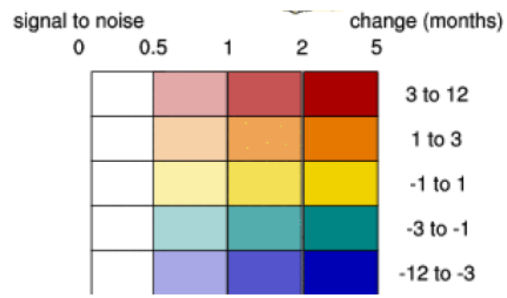
Impact of Climate Change on the length of the malaria transmission season



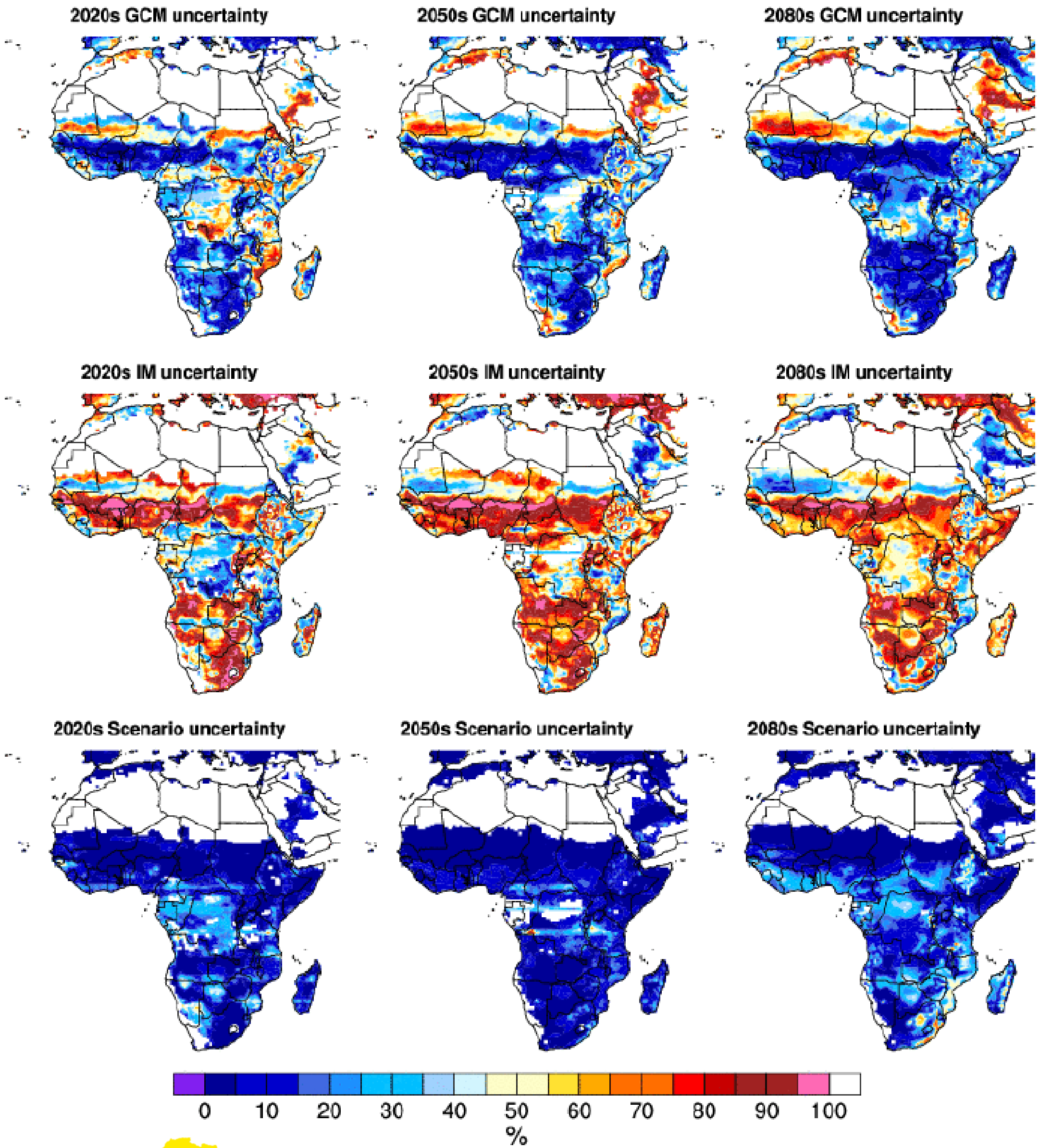
The effect of climate scenarios on future malaria distribution: changes in length of the malaria season (ISI-MIP ensemble).

Each map shows the results for a different emissions scenario (RCP). The different hues represent changes in the length of the transmission season for the mean of CMIP5 sub-ensemble (with respect to the 1980-2010 historical mean). The different saturations represent signal-to-noise (μ/Sigma) across the super ensemble (noise is defined as one standard deviation within the multi-GCM and multi-malaria model ensemble). The stippled area shows the multi-malaria multi GCM agreement (60% of the models agree on the sign of changes if the simulated absolute changes are above one month of malaria transmission).

Increase in transmission over the highlands of Africa (east Africa, Madagascar, Angola, southern Africa) / decrease over the Sahel (extreme scenario / long term)



Various sources of uncertainties: MIM vs GCMs vs RCPs

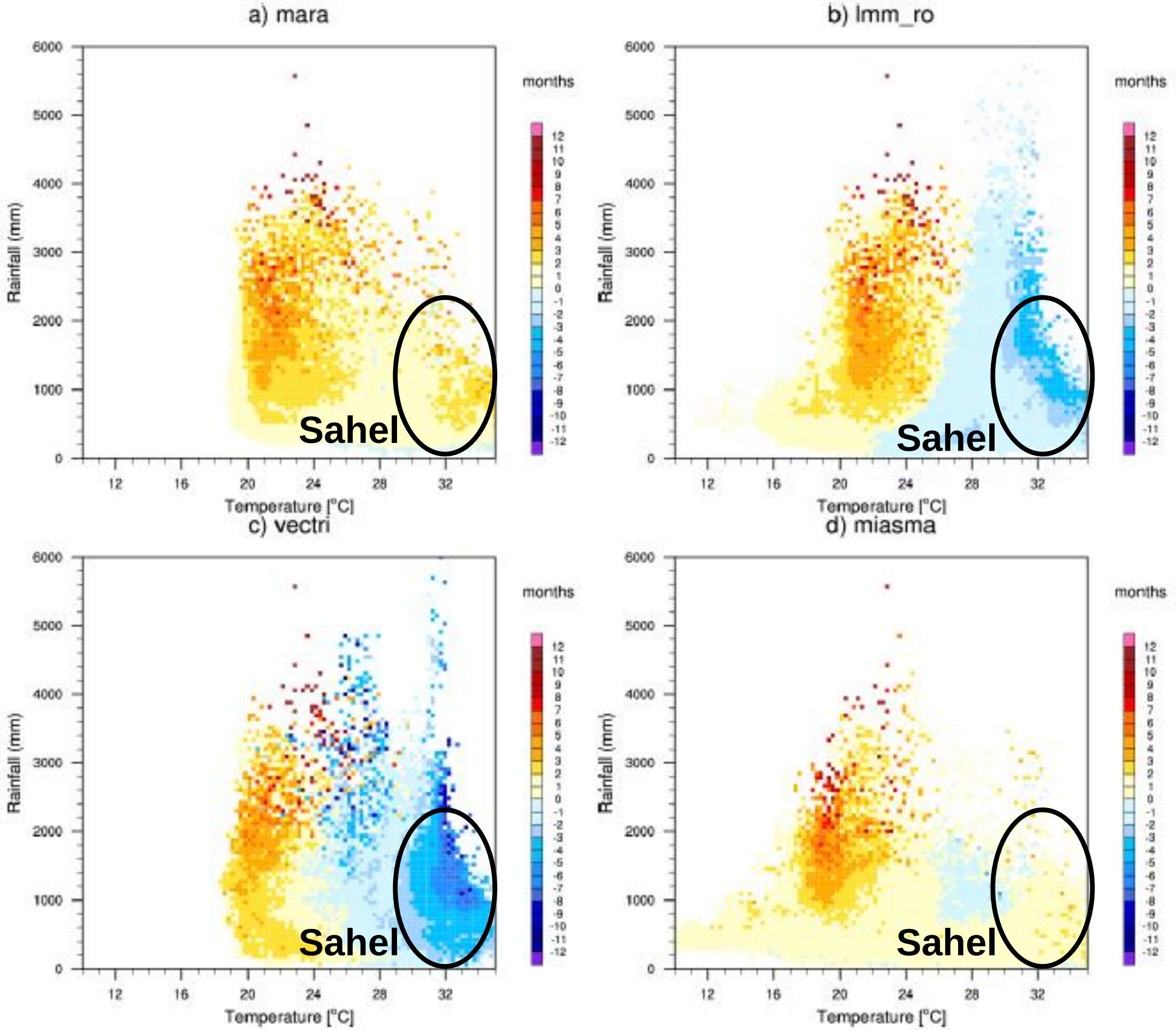


Largest uncertainties related to the method (malaria model)

Uncertainties related to the GCMs huge over the northern epidemic fringe (consistent with the spread in GCM rainfall projections over this region).

Emission Scenario uncertainties increase as a function of time (about 40% over the highlands in 2080s, consistent with a Temperature effect on malaria transmission for those regions).

Malaria Models Sensitivity



Sensitivity of the simulated changes in the length of the malaria transmission season (LTS) to mean annual rainfall and temperature for the ISI-MIP ensemble over Africa.

Mean changes in the length of the transmission season are calculated for all emission scenarios, GCMs and time slices. If the simulated absolute changes are above one month, then they are plotted versus mean future annual rainfall (mm – Y axis) and temperature (°C – X axis). Results are similar for the CORDEX ensemble (not shown).

Mara, miasma: General Increase in LTS

lmm_ro, vectri: Increase in the moderate temperature range, decrease for high temperatures (mosquito survival schemes)

Conclusion

- **20th century trends (globe)**: Decline in malaria endemicity observed over the 20th century at global scale not reproduced by malaria models driven by climate drivers only (Intervention!).
- **20th century trends (Africa)**: Climate induced risk consistent over the Sahel and the highlands.
- **Climate change**:
  - Consistent increase in malaria transmission over the highlands of Africa
  - Southward shift of the epidemic belt / decrease in LTS over the Sahel for vectri & lmm_ro
  - Population at risk generally increases over Africa (population growth driven, not shown)
- **Largest uncertainties in the future are related to the malaria models**
- **RCMs results consistent with GCMs ones (not shown)**