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QWeCI

Quantifying Weather and Climate Impacts on Health in Developing Countries

M4.1b - Pilot Integration of the existing dynamic malaria model with a decadal ensemble prediction system

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Lead contractor: UNILIV
Coordinator of milestone: UNILIV
Evolution of milestone

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Dissemination Level		
PU	Public	PU
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

Context and original plan based on the QWeCI DoW:

Decadal climate prediction is a branch of climate modelling with the theoretical potential to anticipate climate impacts years in advance. The ENSEMBLES multi-model decadal stream 2 hindcasts consist of four forecast systems: ECMWF, HadGEM2, CERFACS and IFM-GEOMAR. All models include the main radiative forcings and none have flux adjustments at the ocean surface. Three members for each model were run for ten years starting on 1st November 1960, 1965 and every five years thereafter until 2005, giving nine hindcast time blocks and one which extends into the future (until 2015).

The original work consisted in driving the dynamic Liverpool Malaria Model with those decadal forecasts to produce malaria decadal hindcasts. Then we had to estimate the skill/value of those decadal malaria hindcasts with respect to a control run driven by reanalysis datasets. The recent work carried out within QWeCI by UNILIV showed that the ENSEMBLES stream 2 decadal ensemble hindcasts system has already low skill in reproducing the observed rainfall and temperature variability (MacLeod et al., 2012). As daily rainfall and temperature are the main inputs of the dynamical malaria model e.g. LMM, those malaria decadal ensemble hindcasts will have consequently a highly limited sense/value over Africa. The main findings about the skill in the ENSEMBLES decadal simulation are summarized in the following paragraph (abstract from MacLeod et al., 2012):

Decadal climate prediction is a branch of climate modelling with the theoretical potential to anticipate climate impacts years in advance. Here we present analysis of the ENSEMBLES decadal simulations, the first multi-model decadal hindcasts, focusing on the skill in prediction of temperature and precipitation - important for impact prediction. Whilst previous work on this dataset has focused on the skill in multi-year averages, we focus here on skill in prediction at smaller time scales. Considering annual and seasonal averages; we look at correlations, potential predictability and multi-year trend correlations. Results suggest that prediction skill for temperature comes from the long-term trend, and that precipitation predictions are not skilful. Potential predictability of the models is higher for annual than for seasonal means, and is largest over the tropics, though it is low everywhere else and is much lower for precipitation than for temperature. The globally averaged temperature trend correlation is significant at the 99% level for all models and is higher for annual than for seasonal averages, however for smaller spatial regions skill is lower. For precipitation trends, correlations are not significantly different from zero at either annual or seasonal scales. ***Whilst climate models run in decadal prediction model may be useful by other means, the hindcasts studied here have limited predictive power on the scales at which climate impacts and results presented suggest that they do not yet have sufficient skill to drive impact models on decadal timescales****.*

New plan and directions:

Given the limited skill in those decadal ensemble hindcasts in reproducing climate trends and climate interannual variability, we could not consider to drive the dynamical Liverpool Malaria Model by simulated rainfall and temperature from those hindcasts at the daily time step. Instead we decided to use a steady state driven version of the LMM which uses monthly rainfall and temperature as inputs (transmission model of the standard LMM, see Methods for further details). This LMM version is currently tested and validated against four other malaria models (MARA, VECTRI, MIASMA and a statistical model) within the ISI-MIP project framework. The ISI-MIP project aims to utilise climate change scenarios carried out for the next IPCC exercise to drive an ensemble of impact models (crop, health...). The uncertainties related to the impact models, the climate models, the emission scenarios and other socio-economic parameters (demography scenarios...) are currently estimated for different time slices in the future. The health modelling exercise focus on malaria transmission changes at global scale for the future (change in future climate suitability for malaria transmission, length of the malaria season, future population at risk...). This work (contracted by the 2nd working group of the IPCC) will lead to a publication in a high impact journal (PNAS) and QWeCI will be gratefully acknowledged (two malaria models used/developed within QWeCI e.g. LMM/Vectri for this work that will have a wide dissemination at the global scale and a large impact).

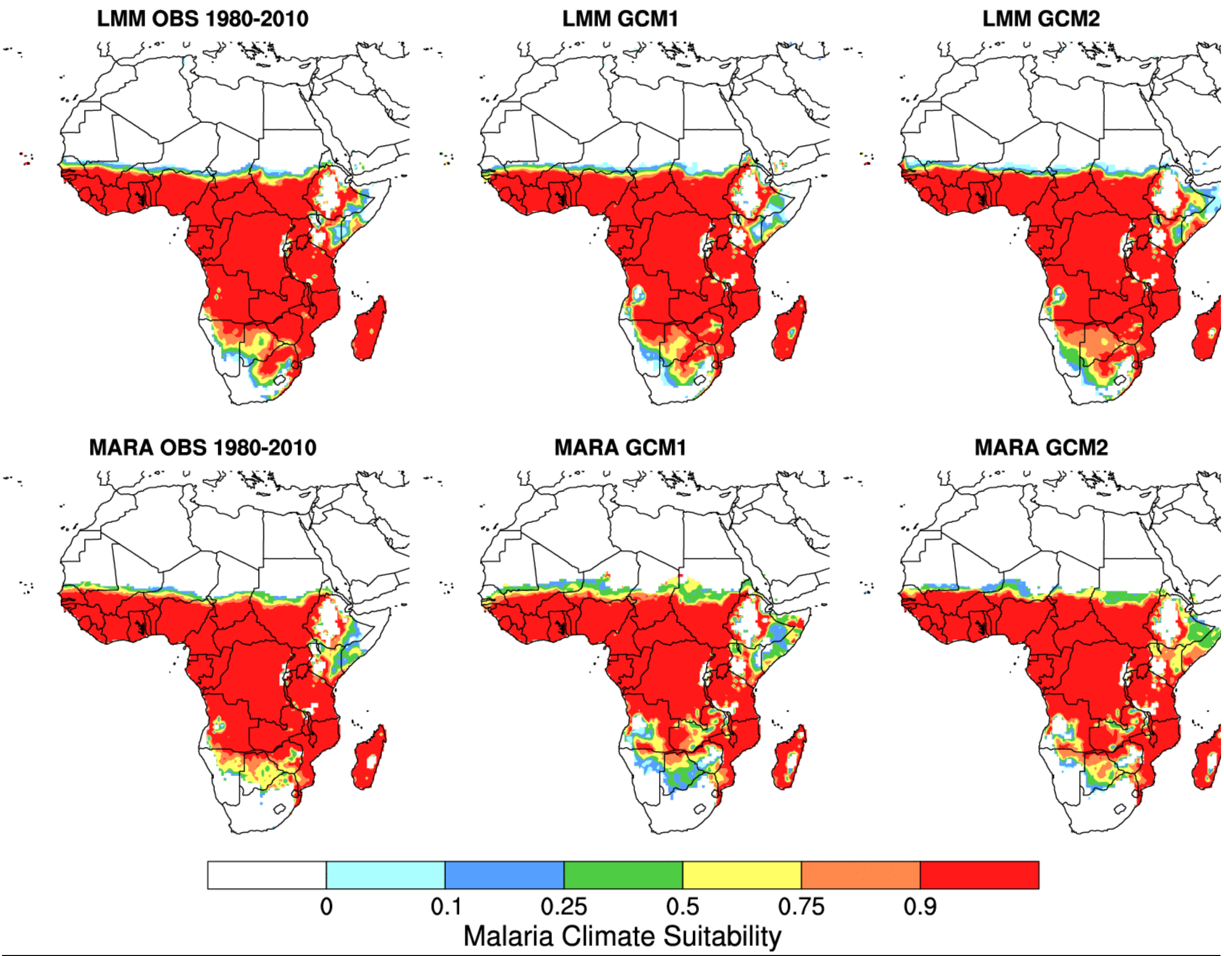

Fig 1: Simulated Climate suitability for Malaria (1980-2010) for two different malaria models (LMM & MARA). The control runs (the malaria model is driven by CRUTS3.1 monthly rainfall and temperature) are depicted on the left column. The malaria model runs driven by GCM1 (hadgem2-es) and GCM2 (ipsl-cm5a-lr) are shown on the middle and right column. Red depicts region where simulated malaria is highly suitable and stable while light blue regions where malaria is unsuitable or

absent.

Bias corrected rainfall and temperature for five different General Circulation Models (GCMs: HadGem2-ES, IPSL-CM5A-LR, MIROC-ESM-CHEM, GFDL-ESM2M, and NorESM1-M) and four different emission scenarios (IPCC RCPs 2.6, 4.5, 6, 8) are employed to drive the LMM and the other malaria models in order to assess the changes in future malaria transmission. This will be combined with UN population scenarios to estimate the future population at risk of malaria. The LMM malaria runs have already been completed for all scenarios and four GCMs.

As an example, Figure 1 shows the climatic suitability for malaria transmission over Africa as simulated by two different malaria models (LMM &MARA), for the control runs (left) and the GCMs runs (middle and right). The Sahelian malaria epidemic belt as simulated by the LMM is slightly shifted southward with respect to MARA, and this extends too far south over southern Africa. Otherwise, both models agree fairly well in reproducing climate suitability for malaria. Figure 2 shows the change in climate suitability for malaria transmission. Results show that both malaria models agree that malaria transmission is likely to occur over the high plateau region in eastern Africa in the future. Malaria transmission might disappear over the northern edge of the western Sahel. However there are large uncertainties over West Africa based on the health impact model. The higher the emission scenario considered, the largest the simulated changes are in future malaria transmission.

Perspectives:

- A more detailed analysis and discussion about the different scenarios in future malaria transmission over Africa will be reported in the QWeCI Deliverable D4.1.b "Report on decadal ensemble prediction system integration with a dynamic disease model".
- As five different malaria models are considered; this work will have strong connection to WP2.1 (Development of dynamic disease models).
- The simplified monthly version of the LMM will be compared with the LMM standard version.
- A prototype using the ENSEMBLES decadal stream 2 hindcasts to drive the monthly version of the LMM will be run. However, as the skill of those hindcasts is highly limited, the outputs of this system will have a **highly limited meaning**. This is why we will mainly focus on malaria climate change scenarios in collaboration with the ISI-MIP project.

Methods:

LMM Monthly Model (Malaria Model 1 for ISI-MIP):
The LMM version used here is a simplified version of the Vector Transmission Potential model formulated by A. Jones. The number of emerging adult mosquitoes at the beginning of each month is taken to be proportional to the rain falling during the previous month. The mosquito population is then combined with the biting rate, sporogonic cycle length and

survival probability calculated from monthly temperatures, together with the other parameters provided as input to the model, to derive the Reproduction Ratio, R_0, corresponding to the transmission model component of LMM. If R_0 >1 then malaria transmission occurs for a given month.

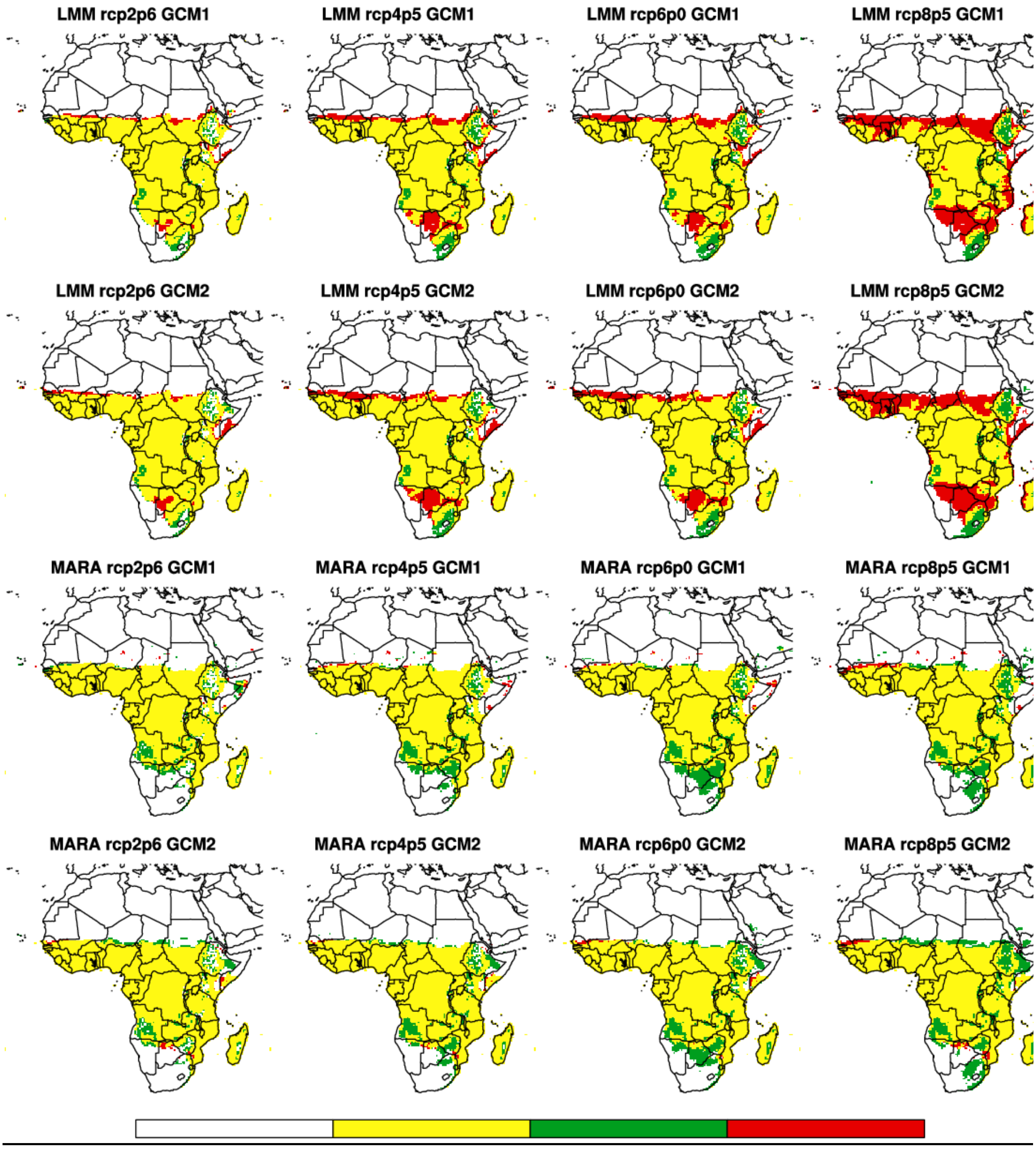

Fig 2: Changes in Climate suitability for Malaria (**2069-2099 vs 1980-2010**) for two different malaria models (LMM & MARA) for an ensemble of emission scenarios (from left to right: from low to high emission scenario) and two different GCMs (GCM1 = hadgem2-es and GCM2 = ipsl-cm5a-lr). White: climate is still unsuitable in the future for malaria transmission Yellow: climate is still suitable in the future; green climate becomes suitable in the future; Red: climate becomes unsuitable in the future.

References:

D.A. MacLeod, C. Caminade, A.P. Morse (2012). Useful decadal climate prediction at regional scales? A look at the ENSEMBLES stream 2 decadal hindcasts. Submitted to Env. Res. Lett (under review).