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QWeCI

Quantifying Weather and Climate Impacts on Health in Developing Countries

Deliverable 5.1.b: Multi Agency System

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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)	

Introduction

Work Package (WP) 5.1 of the QWeCI project developed integrated information and decision support systems based on the scientific output of various other WPs. The main challenge was to transfer complex scientific climate-disease results to the stakeholders in the target countries. In order to put science into action the QWeCI project developed a multi agency system. This system consists of decision support tools such as *Information Systems* (ISs), *Monitoring Tools* (MTs), or *Spatial Decision Support Systems* (SDSSs). These systems were designed following a stakeholder dialogue, which was undertaken by the project partners of the pilot countries. The stakeholder dialogue identified amongst others the requirements and skills of the end-users. This ensured a user-friendly development of the various systems.

Due to the delay of the stakeholder dialogue (D5.1.a) the development of the first systems versions was also delayed. UoC set up a web-based Java framework in which various systems were implemented. In a first step, a pilot system of the multi agency system was developed by the UoC, which supported the stakeholder dialogue since this system can be considered as a prototype system. The pilot system is the online version of the Liverpool Malaria Model (LMM).

The Health Early Warning System consists of four different components. The first component consists of the online version of the LMM, the pilot system of the multi agency system. The second included system is VECTRI (VECtor-borne disease community model of ICTP, TRIeste). The online version of the community malaria model provides a simple access to this complex dynamical weather-driven malaria model. The third system consists of an information system with regard to example malaria forecasts for the Kumasi region. At the end of January 2013, the LMM and VECTRI demonstrate how state-of-the-art weather-driven dynamical malaria models could be used for the local prediction of the malaria transmission season. Lastly, the Health Early Warning System includes operational seamless monthly-to-seasonal malaria forecasts. First prototype pan-African operational seamless forecasts are available from VECTRI and the LMM. Both dynamical weather-driven malaria models predict the potential transmission intensity with a lead-time of up to 120 days.

A pond information system with regard to the Ferlo area was further developed for the multi agency system. CSE provided information in terms of monitored water ponds near the Barkedji village in Senegal. Presented are photos from the ponds and when the weather and hydrological stations were installed. Illustrated are the observed rainfall amounts and the resulting water levels of the ponds. Furthermore, an elevation map and three-dimensional view of three ponds is available. The water volume of the ponds is associated with the attendance of people and livestock at the ponds. The ponds are potential breeding sites for mosquitoes and the availability of breeding habitats depends on the size of the ponds.

IPD reviewed the malaria and Rift Valley fever control measures of Senegal. The results of this study are included in an information system. IPD further designed a SDSS with regard to a developed statistical Rift Valley fever model, which relates environmental such as meteorological variables to the density of Aedes vexans and Culex poicilipes in six different biotopes.

UNIMA already successfully constructed the monitoring tool of near-real time disease

incidence in health clinics of Malawi. This system is a stand-alone system and needs not to be included into the web-based Java framework of the UoC.

The multi agency system therefore consists of the following online systems:

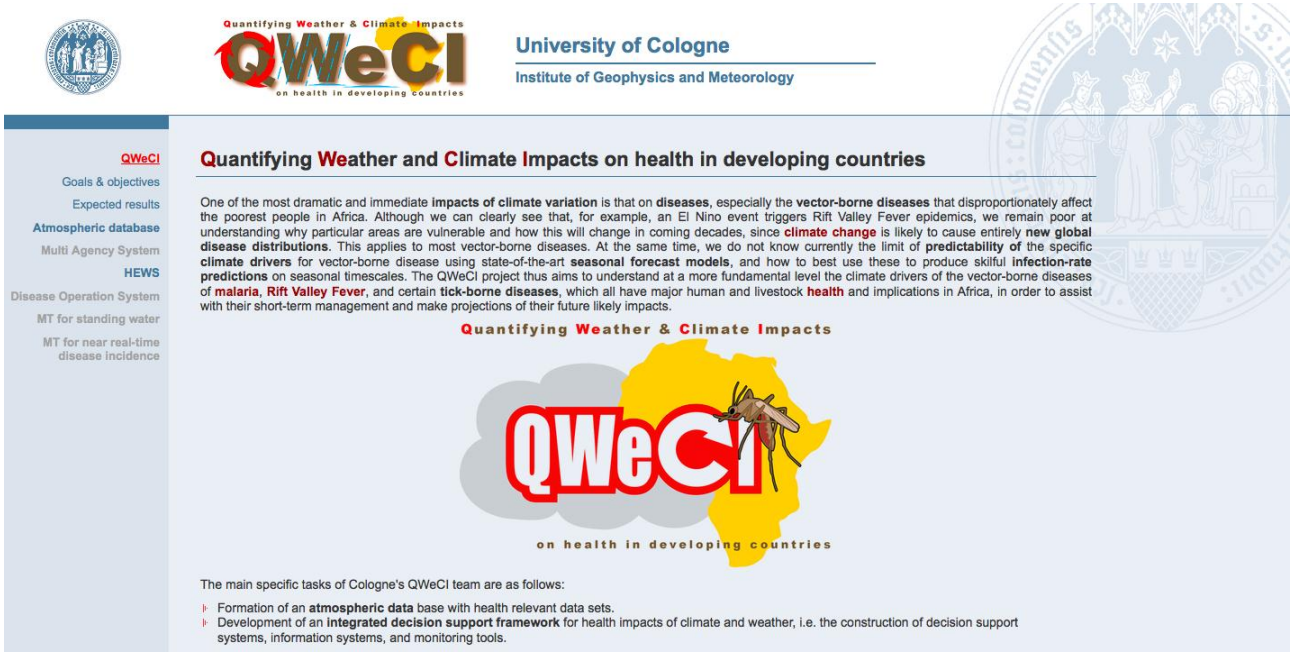
1) Health Early Warning System
   - Liverpool Malaria Model (online version for point data)
   - VECTRI (online version for point data)
   - Malaria Early Warning System (Example malaria forecasts for the Kumasi region)
   - Operational monthly-to-seasonal malaria forecasts (link to the ECMWF web portal)
2) Monitoring of Ponds in the Sahel
   - Pond Information System of the Ferlo area
3) Disease Operation System
   - Review of malaria & Rift Valley fever control measures
   - Rift Valley fever vector model
4) The Monitoring Tool of near-real time disease incidence in Malawi health clinics (link to the Health Information System Program of Malawi)

When the DoW was constructed it was planned that the multi agency system would be based on disease impact model simulations of WP4.1 in terms of monthly-to-seasonal and decadal time scales. However, WP4.1 intended only to provide malaria hindcasts. For this reason, UoC set up a meeting at the General Assembly of the European Geophysical Union. It was decided that ICTP would set up VECTRI at the ECMWF server for the production of prototype monthly-to-seasonal malaria forecasts. UNILIV later decided also to include LMM into the ECMWF system management software. Note that the set up of both VECTRI and LMM was supported by ECMWF and the ECMWF generated an online operational malaria forecasts web portal.

The web-based Java framework

For the development of the multi agency system UoC set up a web-based Java framework. The web-based Java framework includes:

- A virtual Linux machine (qweci.uni-koeln.de).
- The usage of Apache Tomcat (version 6.0.26), which is an open source servlet container providing a 'pure Java' web server for Java code to run.
- The application of Java, which is an open source, class-based and object-oriented programming language.
- The utilisation of the *Google Web Toolkit* (GWT, version 2.4.0). GWT is open source and represents a development toolkit for building and optimizing complex browser-based applications. The GWT *Software Development Kit* (SDK) provides a set of core Java *Application Programming Interfaces* (APIs) and widgets, which was used for the set up of various systems of the multi agency system of WP5.1.

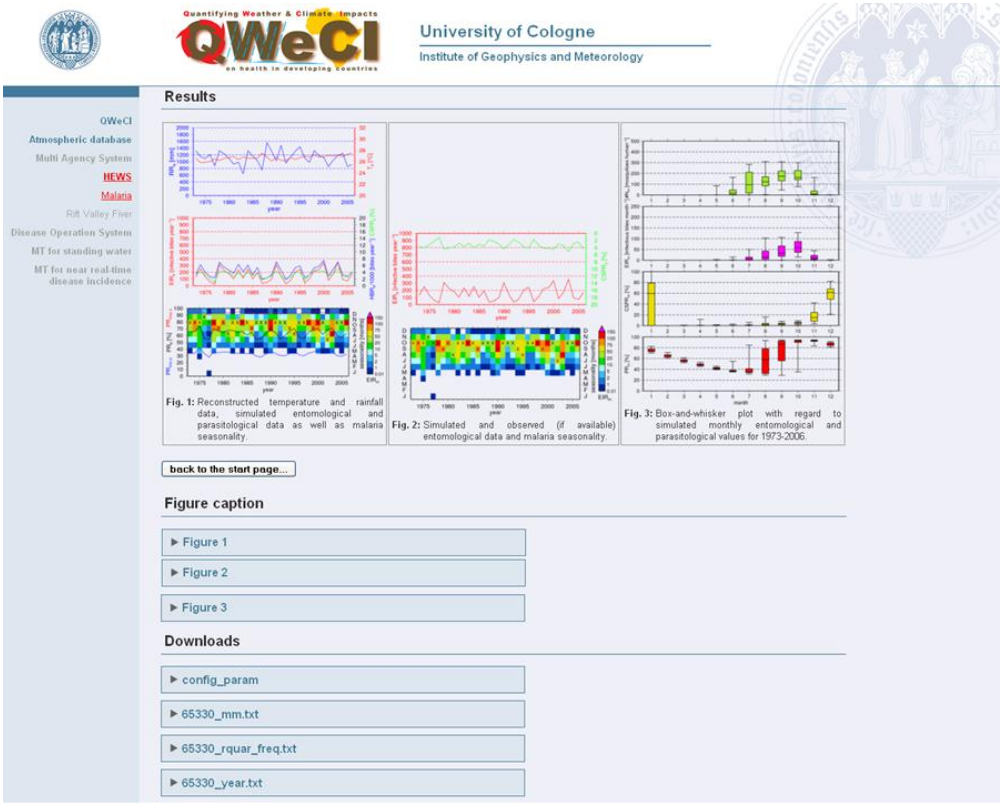


Web- portal as based on the Java framework of the UoC regarding QWeCI available at http://qweci.uni-koeln.de.

1) Health Early Warning System

Liverpool Malaria Model (online version for point data)

In order to represent parts of the application spectrum of the web-based Java framework a pilot system was developed. The version 1.0 of the pilot system was constructed. The system makes use of the so-called *Liverpool Malaria Model* (LMM), which is a weather-driven malaria model that is driven by daily temperature and rainfall data (see Hoshen and Morse 2004). The system is primarily intended for the construction of specific sets of parameter settings for the QWeCI pilot regions (e.g. for rural and urban areas of Kumasi). Users can, for example, use their own data to run the model and to see if the model is able to reproduce their local malaria conditions. Due to the lack of calculating capacity of the QWeCI server, the model runs can only be performed for specific locations.



Final page of the web-version of the LMM that includes the output data as well as pre-defined figures of the LMM simulation.

In the version 1.0 of the pilot system, the user is able to run the *LMM version of 2004* (LMM_{2004}; Hoshen and Morse 2004), *that of 2010* (LMM_{2010}; Ermert et al. 2011a,b), as well as by a self-defined set of parameter setting. Model runs can be performed for 34 synoptic weather stations in West Africa (including three stations in Cameroon) covering the period 1973 to 2006. The user can also use his own temperature and rainfall time series for running the LMM. The model output can be analyzed by means of three pre-defined figures, which are visualizing eleven entomological and parasitological malaria variables.

VECTRI (online version for point data)

VECTRI is a high-resolution dynamical weather-driven malaria model, which accounts for population density and surface hydrology. This model can run on a two-dimensional grid or for a single point. To set up the model skills in terms of Linux and shell scripting are required. For this reason, an online version of VECTRI was included into the web-based Java framework. The alpha version of the online tool is available for the user meaning that some bugs need to be fixed in the near future.

The logo of VECTRI (preliminary version).

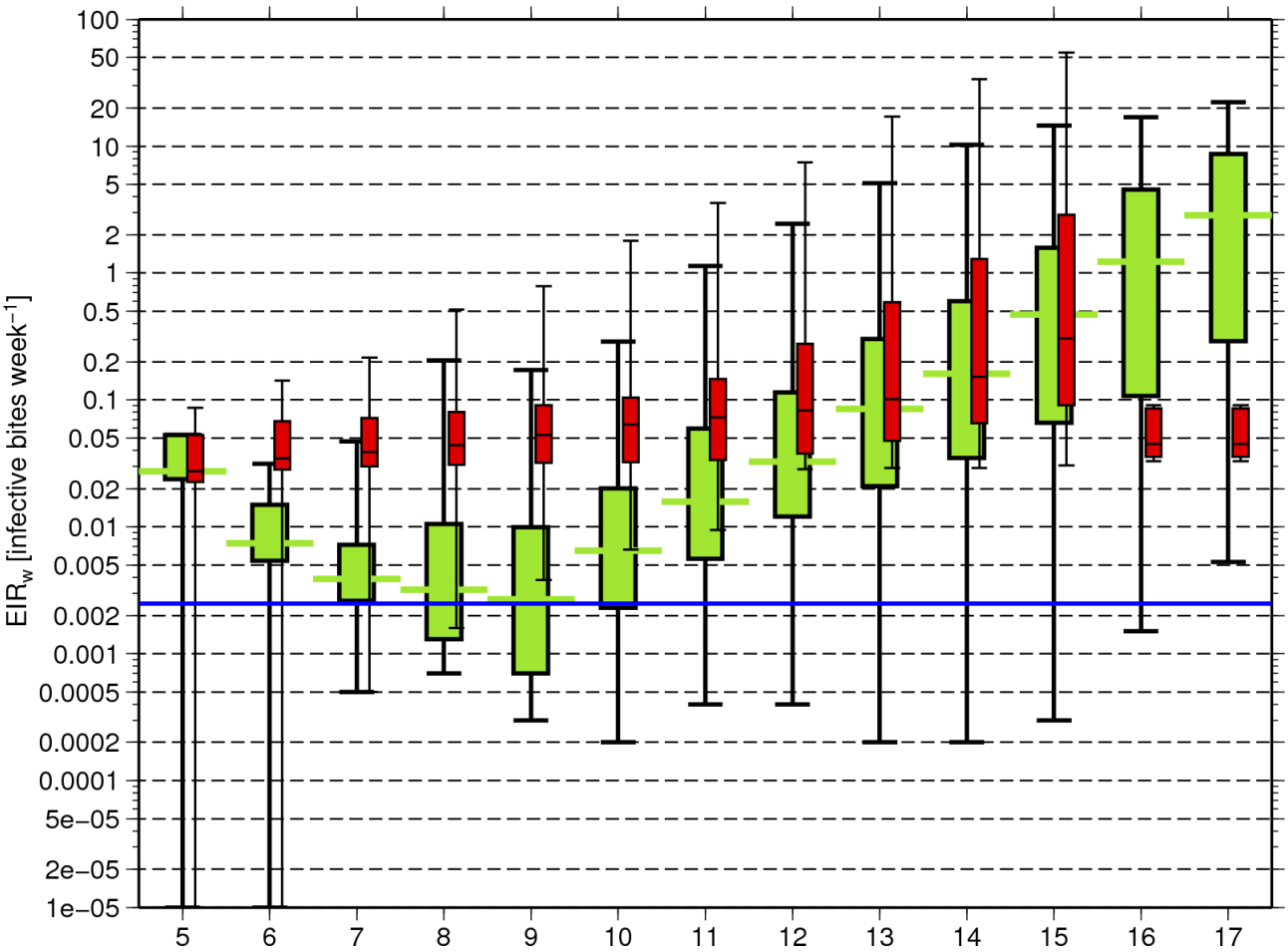
The users can set up their own parameter settings of the model or can use the default setting of VECTRI. After running the model, the results of the model runs are comparable to the online LMM version visualized by three graphics. Simulated are entomological and parasitological malaria variables. The user can upload his own data to drive VECTRI with other than the provided atmospheric conditions. He is also able to change the value of the VECTRI model parameters like the population density. The increase in the population density for urban areas, for example, strongly reduces the transmission intensity.

First page of the online VECTRI version. The user is able to change the parameter setting of VECTRI.

Malaria Early Warning System

In order to show the feasibility of local malaria forecasts, the Health Early Warning System

includes further demonstrative malaria seamless monthly-to-seasonal malaria forecasts for the Kumasi region (see Task 5.2.e). Illustrated were the seamless malaria forecasts from January 2013. The results of these example malaria forecasts are included into the multi agency system. In contrast to the forecasts from the ECMWF, the local forecasts mainly focus on the generation of time series of key malaria variables. In January 2013, the lead-time of 120 days includes the start of the main malaria transmission season, for which the forecast is provided by VECTRI and LMM.



Demonstrative monthly-to-seamless malaria forecast (starting from 31 January 2013) of the Liverpool Malaria Model (LMM) for the Kumasi region in Ghana: Illustrated is the weekly Entomological Inoculation Rate (EIR_w; i.e. the number of infectious mosquito bites per person per week) on a log scale between the beginning of February (week 5) and the end of May 2013 (week 17) from 51 forecast ensemble members (green box-and-whisker plots) for 2013 and from 90 hindcast ensemble members between 1995 and 2012 (red box-and-whisker plots). The blue horizontal line indicates the status when the LMM simulates that one person is bitten by an infectious mosquito per month.

The malaria forecast starts at the beginning of February (week 5) and finishes at the end of May 2013 (week 17). The forecast includes entomological and parasitological malaria variables. Included is, for example, the simulated Entomological Inoculation Rate (EIR; i.e. the number of infectious mosquito bites per person per time). The weekly EIR median value of the 51 ensemble members of the malaria forecasts is always higher than 0.25 infectious bites per 100 people meaning that transmission is ongoing also during the driest period of the month. However, the risk of a malaria infection is fairly low at the beginning of

March (week 9). The transmission intensity is predicted to increase toward the end of the simulation period. In week 17, the weekly EIR value is about two infectious bites per person indicating the set up of the main malaria transmission season of the Kumasi region. Malaria transmission is forecasted to be below average as compared with the seasonal hindcasts (period: 1995-2012).

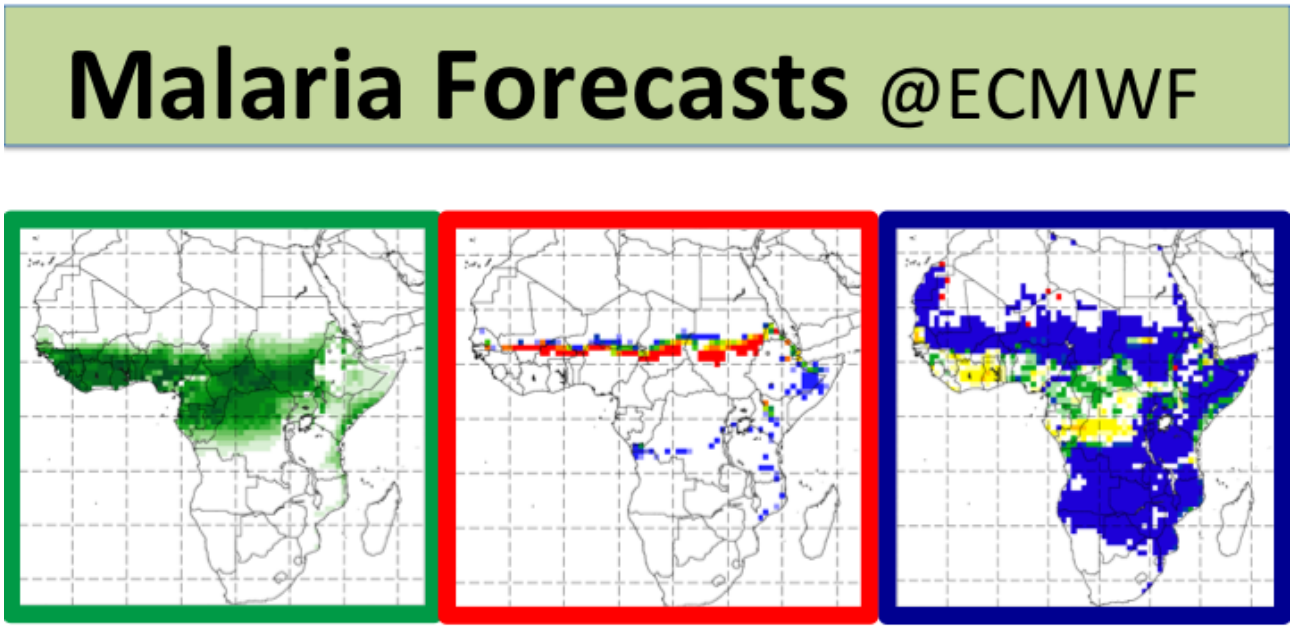
Operational monthly-to-seasonal malaria forecasts

Prototype malaria forecasts were developed by the QWeCI project. The first pan-African operational seamless monthly-to-seasonal malaria forecasts are available from dynamical weather-driven malaria models.

The malaria model VECTRI was implemented by the project partners ICTP and ECMWF into the ECMWF system management software. In summer 2012, VECTRI was integrated into the ECMWF forecasting system and uses a calibrated seamless monthly-to-seasonal weather forecast from the ECMWF. The malaria forecasts are generated on a weekly basis (every Thursday) with a lead-time of 120 days (i.e. four months) and are available at a ECMWF web portal:

http://nwmstest.ecmwf.int/products/forecasts/d/inspect/catalog/research/qweci/

Available are precipitation and temperature maps from the calibrated and non-calibrated monthly-to-seasonal weather forecasts. This data is used for the malaria forecasts in terms of the Entomological Inoculation Rate (i.e. the number of infectious mosquito bits per human) and the parasite ratio (i.e. the proportion of the population that is infected by the malaria parasite). Maps are provided for the hindcast period and a probability map represents the probability that transmission is below, normal, or above the average value.



The prototype seamless monthly-to-seasonal meteorological and malaria forecast system provides entomological and parasitological malaria forecast maps.

Note that the forecasts need to be verified against reality. At present, no real-time malaria observations are available for this task. This will be a possible follow-up investigation of the QWeCI project.

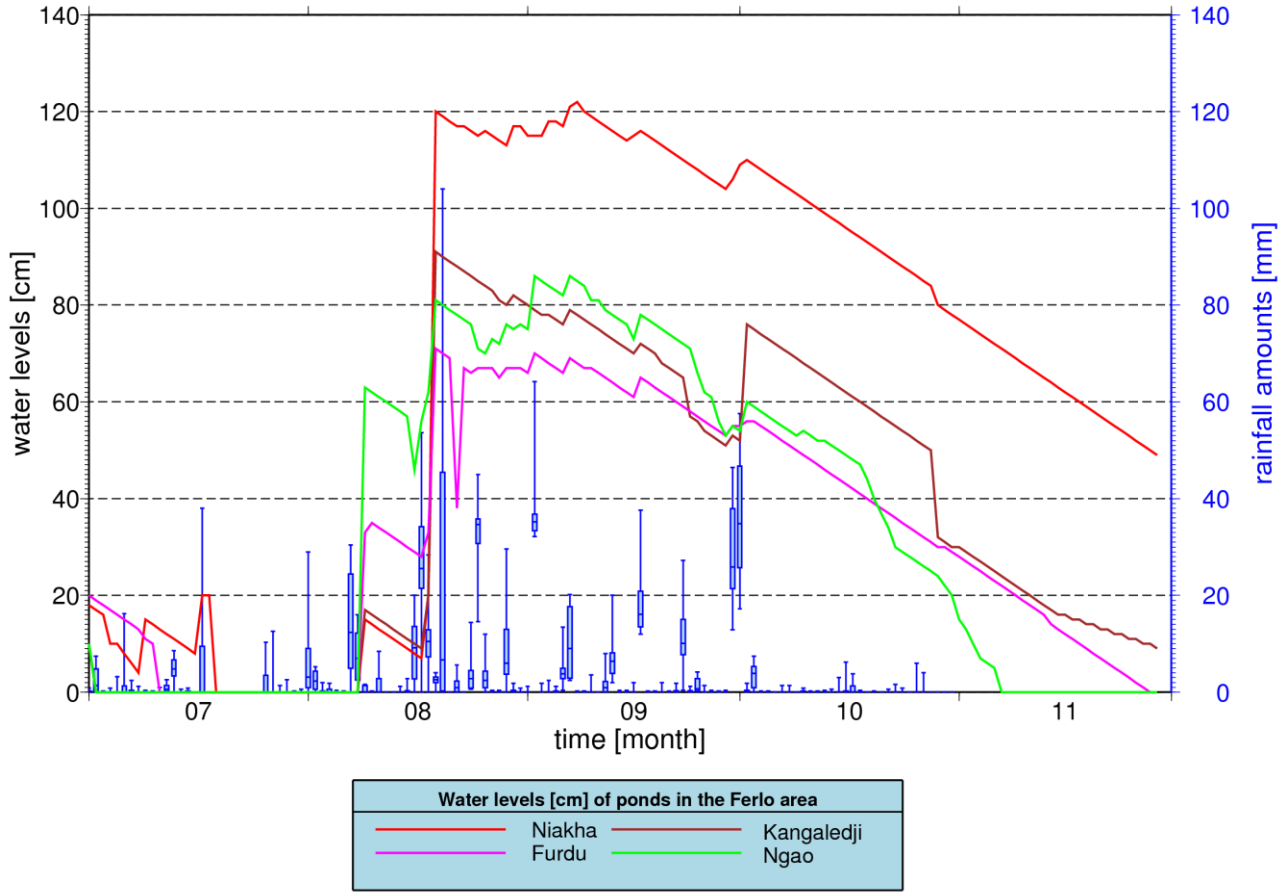
The Liverpool Malaria Model (LMM) was also integrated into the ECMWF system. This model is about to start malaria forecasts in addition to that of VECTRI. Available will be malaria forecast from both the 2004 and 2010 versions of the LMM. For this reason, the prototype malaria forecasts will become a multi malaria model ensemble malaria prediction system. Of course, this system needs to be verified against malaria observations to show if the prediction system is able to provide forecast skills for this disease.

2) Monitoring of Ponds in the Sahel

Pond Information System of the Ferlo area

The Pond Information System of the Ferlo area includes hydrological pond measurements from a Sahel region near the Barkedji village of Senegal. Presented are the most interesting results like the intra-seasonal variability of the water level of the ponds. The variability of the water volume is associated with the dry season in boreal winter and the rainy season during the West African summer monsoon.

The water volume of the ponds is associated with the attendance of the local population and their livestock at the ponds. The monitored ponds further serve as breeding sites of mosquitoes such as malaria and Rift Valley fever vectors. The availability of breeding habitats for these disease vectors depends on the size of the ponds. Therefore, also the information in terms of the surface of the ponds is of special interest.



Intra-seasonal variability of water levels (in cm) from the Furdu, Ngao, Niakha, and Kangaledji ponds of the Ferlo region. Measurements are available between 01 July and 29

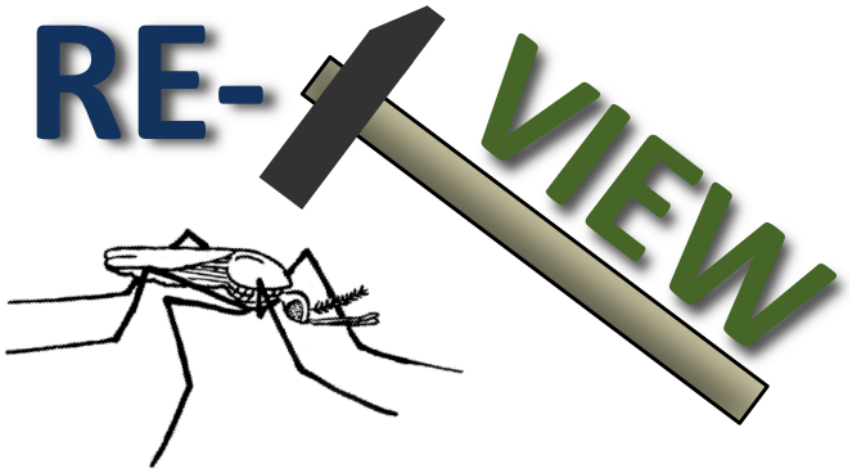
November 2011. Included are also box-and-whisker plots with regard to observed rainfall amounts from twelve rain gauges of the Ferlo area.

Included in the information system are photos from the ponds and the installation of the weather and hydrological stations. Three- and two-dimensional views and elevation maps are available from three ponds. A high-resolution false colour composite satellite image illustrates the Barkedji Health and Environment Observatory, which includes the monitored ponds. Moreover, equations regarding the water volume and surface of the ponds were included.

3) Disease Operation System

Review of malaria & Rift Valley fever control measures

This information system includes a review of malaria and Rift Valley fever control measures in Senegal. IPD described that the key malaria control measures were (i) Insecticide Treated Nets (ITNs), (ii) Rapid Diagnostic Tests (RDTs), (iii) Artemisinin-based Combination Therapies (ACTs), and (iv) Indoor Residual Spraying (IRS).

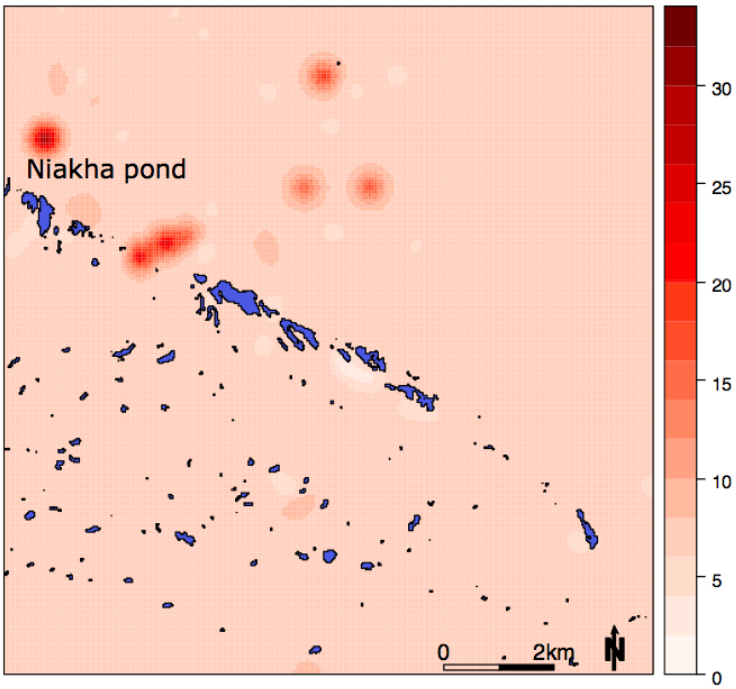


Reviewed were control measures in terms of the malaria and Rift valley fever diseases.

Regarding the Rift Valley fever disease the only available control method was the prevention of the disease. As a prelude, IPD is developing a statistical Rift Valley fever vector model to forecast the distribution of the two Rift Valley fever vectors.

Rift Valley fever vector model

A statistical Rift Valley fever vector model was constructed by IPD. Exploited were entomological and environmental observations in the Ferlo region of the Sahel. This statistical model is driven by environmental observation such as precipitation amounts and temperature values. It reproduces the intra-seasonal variability and spatial distribution of the two Rift Valley fever vectors Aedes vexans and Culex poicilipes, which would therefore represent a spatial decision support system.



Simulated spatial distribution of the number of Rift Valley fever vectors (Culex poicilipes) within the Ferlo area for the first half of October 2005.

Mosquito collections from 2005 were used from the Ferlo area to calibrate the parameters of the model. It was not possible to include the Rift Valley fever vector model into the web-based Java framework due to the WinBUGS software that is used by the model. The Java framework is set up within the Linux operating system. Another problem would also prevent to run the model in the framework. The model simulations requires about 10 minutes to be finished, which is not acceptable from the user's point of view.

Instead of running the model on the framework, the example model results for 2005 are interactively presented within an information system. Time series can be generated for six different biotopes. Vector distribution maps of the area can be produced for fortnightly periods of 2005.

The Monitoring Tool of near-real time disease incidence in health clinics

UNIMA successfully constructed the MT of near-real time disease incidence in health clinics of Malawi. This system is a stand-alone system and is not be included into the web-based Java framework of the UoC. However, the multi agency system provides a web link to the Health Information Systems Program (HISP) of Malawi.

In the preparatory stages of the monitoring development, a preliminary study of the format, quality, and availability of the malaria incidence rate and meteorological data from individual locations was undertaken. In the following, the UNIMA was setting up the so-called *district Health Information System version 2* (dHIS2) of the University of Oslo (available from http://www.dhis2.org). The dHIS2 is a web-based information system (available under the password protected web page http://www.hispmalawi.org.mw) and was implemented at the UNIMA under the Linux Ubuntu platform. The IS is developed for the Malawi Ministry of Health and is used for the following purposes:

- Definition of data elements such as monthly malaria reports from health clinics
- Collection of disease data from health facilities in Malawi
- Serves as an data archive of disease incidence data in Malawi and provides quality checks of the data
- Visualization of time series of disease incidence data
- Computation of indicators of disease outbreaks and for the provision of early warnings
- Measures the impact of control measures/intervention
- Provides an assessment of the quality of outreach programs of the Ministry of Health (Is there a decline of, e.g. malaria cases, after the training of health facilities?)
- Construction of disease incidence reports that include predefined graphs and analyses
- Includes a Geographic Information System component, which is able to map the disease incidence data

Dashboard of the dHIS2 as providing analyses and pre-defined figures (source:

http://www.dhis2.org).

After the successful implementation of the system disease incidence data was digitized and inserted into the incidence database of the dHIS2. Training was provided at the facility and district level. Note, the data is usually collected and digitized at the district level. One key element in terms of the provision of the data was the WiFi link that was installed by ICTP in collaboration with UNIMA.