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FINAL WORKSHOP REPORT

Climate Variability and Change: Implications for Malaria Control and Elimination in Africa

A Research Capacity Building Workshop

Addis Ababa, Ethiopia

April 28-30, 2014

Acknowledgements

Organizing Host

Ethiopian Public Health Association (EPHA)

Workshop Organizing Institutions

School of Public Health at Addis Ababa University (SPH-AAU)
Ethiopian Public Health Institute (EPHI)
International Research Institute for Climate and Society (IRI), Columbia University
Columbia Global Centers | Africa (CGC Africa)
Health and Climate Foundation (HCF)

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Acronyms

AAU	Addis Ababa University
ABP	Alonso, Bouma and Pascual's Malaria Process-based Model
ACTs	Artemisinin-based Combination Therapies
ACIPH	Addis Continental Institute of Public Health
AFENET	African Field Epidemiology Network
AFPHA	African Federation of Public Health Associations
AFRO	WHO Regional Office for Africa
AM	Anderson and May's Malaria Process-based Model
CCA	Canonical Correlation Analysis
CCAA	Climate Change Adaptation in Africa
CDC	Centers for Disease Control and Prevention, USA
CGC Africa	Columbia Global Centers | Africa
CHWG	Climate and Health Working Group
CIESIN	Center for International Earth Science Information Network, Columbia University
CIPHA	Climate Information for Public Health Action
CIPHAN	Climate Information for Public Health Action Network
ClimDev-Africa	Climate for Development in Africa Programme
CPT	Climate Predictability Tool
CRM	Climate Risk Management
DJF	December-January-February Season
EHNRI	Ethiopian Health and Nutrition Research Institute, now EPHI
ENACTS	Enhanced National Climate Services
ENSO	El Niño–Southern Oscillation
EPHA	Ethiopian Public Health Association
EPHI	Ethiopian Public Health Institute
FELTP	Field Epidemiology and Laboratory Training Program
FMOH	Federal Ministry of Health
GIS	Geographic Information System
HCF	Health and Climate Foundation
IPCC	Intergovernmental Panel on Climate Change
IRI	International Research Institute for Climate and Society, Columbia University
IRS	Indoor Residual Spraying
LLIN	Long-lasting Insecticidal Nets
LST	Land Surface Temperature
MAC	Ross-Macdonald's Malaria Process-based Model
MACEPA	Malaria Control and Evaluation Partnership in Africa

MAM	March-April-May Season
MDGs	Millennium Development Goals
MLR	Multi-Linear Regression
MMMP	Multi-Model Malaria Platform
MODIS	Moderate Resolution Imaging Spectroradiometer
MoH	Ministry of Health
MoU	Memorandum of Understanding
MSE	Mean Squared Error
NGO	Non-Governmental Organization
NIH	National Institutes of Health
NMA	National Meteorological Agency
NMCP	National Malaria Control Program
NTD	Neglected Tropical Diseases
OND	October-November-December Season
PCR	Principal Component Regression
PHE	Population, Health and Environment
PHEM	Public Health Emergency Management
ROC	Relative Operating Characteristic
RDT	Rapid Diagnostic Test
REACH	Regional East African Community Health
RVF	Rift Valley Fever
SI-CIPH	Summer Institute on Climate Information for Public Health
SPH	School of Public Health
SST	Sea Surface Temperature
STAC	Scientific and Technical Advisory Committee
TAC	Technical Advisory Committee
TAMSAT	Tropical Applications of Meteorology using SATellite data and ground-based observations
UNECA	United Nations Economic Commission for Africa
UNFCCC	United Nations Framework Convention on Climate Change
UNFPA	United Nations Population Fund
USAID-PMI	United States Agency for International Development – President's Malaria Initiative
VBD	Vector-Borne Disease
WCT	Worrall, Connor and Thomson's Malaria Process-based Model
WFPHA	World Federation of Public Health Associations
WHO	World Health Organization
WMO	World Meteorological Organization

Executive Summary

In Ethiopia, malaria continues to be a major public health concern with an estimated two thirds of the national population at risk of infection. Tackling a key driver, this workshop was convened to advance the understanding of the impact of climate variability and change in relation to the malaria burden to better inform policy decisions related to current control and future elimination strategies. To achieve this, the workshop explored data, methodologies and tools that could be used by national public health researchers to improve malaria risk assessments.

The motivation for the workshop came from an NIH funded project entitled "Climate Variability and Change: Implications for Malaria Control and Elimination in Africa" with the goal of supporting malaria researchers in affected countries in East Africa to identify opportunities for improving the effectiveness of prevention, control and elimination strategies by incorporating an understanding of likely short and longer term changes in the climate in their analysis. In particular, the workshop aimed to address the challenge of varied drivers of the climate, acting at multiple timescales including year to year variability, 10-20 year climate shifts and long term trends associated with climate change.

Data sources explored during the workshop included the newly developed Enhanced National Climate Services (ENACTS) rainfall and temperature products disseminated by the Ethiopian National Meteorological Agency (NMA), as well as globally available climate products freely distributed online. The Climate Predictability Tool (CPT), developed by the International Research Institute for Climate and Society (IRI), to assist climatologists in making robust predictions was tested for the first time as a potential tool for the malaria research community to assess the relationship of malaria to large-scale climate processes. In addition, a multi-model malaria platform (MMMP) was presented during the workshop to explore uncertainty associated with the predictability of malaria over time using a series of process-based models.

Workshop Objectives, Expected Outcomes and Background Documents

Overall meeting objectives

The primary objectives of the workshop were to showcase available information and tools to support the research community to explore the impact of climate variability and change on malaria prevalence and to elicit discussion on current needs and recommendations for improved decision-making.

In particular, the three-day workshop consisted of the following main components:

1. Review the challenge that climate variability and change pose to malaria prevention, control and elimination at multiple time and space scales.

2. Engage in hands-on training and update data and tools available for analysis including:

    - ENACTS (Enhanced National Climate Services) rainfall and temperature products
    - Climate Predictability Tool (CPT)
    - Multi-Model Malaria Platform (MMMP)

3. Explore malaria indices, intervention and socio-economic data for use in local and national malaria models.

4. Discuss implications for policy and decision-makers of the impact of climate variability (ENSO and decadal) and longer-term climate changes for malaria control and elimination.

Expected outcomes

The workshop was expected to provide a unique opportunity for unpacking the implications of a changing climate for national malaria control and elimination strategies in Ethiopia, prioritizing a scientific community of practice and aiming to facilitate an informed discussion on current trends and future possible scenarios.

Specific expected outcomes of the workshop included:

- Participant feedback collected on the use of ENACTS data, CPT and MMMP in malaria-climate analyses.
- Participant feedback collected on the relevance, availability and quality of key socio-economic data that could be used to improve the malaria-climate models.
- Summary recommendations for future research and policy engagement.

A poster/paper emerging from this workshop is further expected to be submitted to the Healthy Futures conference on “Climate Change and Vector Borne Diseases: Past, Present and Future” to be held in Kigali, Rwanda from November 18-21, 2014.

Organisation and Sponsorship

The workshop was convened by the School of Public Health at Addis Ababa University (SPH-AAU), the Ethiopian Public Health Institute (EPHI) and the Ethiopian Public Health Association (EPHA), with funding and technical support from the United States National Institutes of Health (NIH), the International Research Institute for Climate and Society (IRI), the Columbia Global Centers | Africa

(CGC Africa) and the Health and Climate Foundation (HCF). Twenty participants were invited to attend the three-day meeting in Addis Ababa, April 28-30, 2014 with final attendance by 26 researchers, practitioners and facilitators.

Outcomes and Recommendations

Following presentations, technical hands-on sessions and open discussions, participants were asked to respond to the questions below. Included here are the consensus recommendations and feedback of the participants at the workshop:

A. *What are the priority activities going forward?*

	This Year	Next 3 years
Research	• Conduct follow-up survey on use of climate information by health sector at all levels. • Rapid assessment of awareness of El Niño in the health sector. • Use results of Malaria Indicator Survey and other instruments to assess impact of climate. • Desk review of impact of El Niño on malaria in previous years. • Create research team led by EPHI and NMA to investigate El Niño impact on health.	• Establish Climate and Health Collaborating Center. • Identify inter-sectoral research agenda (climate, water, nutrition, migration). • Build more evidence through research on climate-malaria • Engage national academic and research institutions
Education and Training	• Identify opportunities for targeted training for practitioners and implement with partners	• Formal climate and health curricula at the undergraduate & postgraduate level in SPHs. • Develop inter-sectoral collaborations/curricula between departments and schools. • Institutionalize climate in routine FMOH malariology, EPHI Training Center, FELTP programs.
Awareness and Advocacy (Key messages	• Policy brief on El Niño to FMoH, EPHI, NMCP, TAC with clear language on climate and impact uncertainties, opportunities and threats. • Updated advisories on El Niño with	• Incorporation of malaria and health outcomes in the broader climate & development agenda (e.g. PHE).

at policy, practitioner & community level)	supporting evidence. • Routinely updated climate and health bulletins and briefings from NMA/EPHI.	
Services	• Identify districts most at risk of El Niño impacts. • Provide technical support to PHEM on emergency preparedness for El Niño. • Ensure routine access to ENACTS (in terms of infrastructure and protocols). • Ensure better information flow at all levels.	• Develop operational Early Warning Systems. • NMA to co-develop products tailored to sectors.
Data	• Assess available malaria data (morbidity and mortality) and explore methodologies for triangulation and incorporation in climate analysis. • Add additional parameters to ENACTS and lengthen time series.	• Improve monitoring systems, databases, data access and flow. • Demonstrate value of data through publications and use.

B. *What are key recommendations for improving and using the data and tools presented during the workshop (CPT, MMMP, ENACTS) and potential new products?*

1. Develop new products using ENACTS for El Niño preparedness.

2. Make ENACTS routinely available.

3. Use ENACTS in NMA malaria bulletin.

4. Test CPT and MMMP with Ethiopian data.

5. Identify opportunities for follow-up training (1-2 weeks) with tailored CPT and MMMP to Ethiopian context.

C. *What are key concrete next steps over the coming year?*

1. Participants to review and disseminate final workshop report and recommendations to their networks (May 2014).

2. EPHI, SPH-AAU, NMA and IRI to develop El Niño policy briefing (June-July 2014).

3. EPHI, SPH-AAU, NMA and partners to establish team focused on El Niño with agreed activity plan following workshop report and initial review (July 2014).

4. Present workshop outcomes at future international conferences (e.g. Healthy Future November 2014 meeting in Kigali, ASTMH).

5. EPHI, SPH-AAU and NMA led research team to explore publication with partner academic institutions (December 2014).

Conclusion

The workshop achieved its basic objectives of introducing the health research community in Addis Ababa, Ethiopia to new data, methodologies and tools for assessing the relationship between climate and malaria. However the short timeframe of the workshop meant that participants were unable to fully exploit the resources presented and discuss the meaning of results. Despite the constraints of the three day workshop, participant feedback based on initial exposure to the ENACTS, CPT and MMMP products was generally positive. Specifically, ENACTS was identified as relevant to current control issues, while a shortage of longer time series malaria data indicated a limited use of CPT and MMMP in Ethiopia. There was a clear demand for further training on these and other potential tools, however, to support an improved understanding of climate impacts on malaria and its potential predictability.

The news of an increasingly high probability of an El Niño this year was a key focus of the workshop and many discussions centered on practical recommendations for engaging policy makers that could be taken up in the coming weeks and months. It was agreed that the El Niño provided both risks and opportunities to the achievement of Ethiopia's malaria control and elimination strategies. Potential risks included expected higher levels climate suitability for malaria in some regions, while expected benefits included the opportunity to demonstrate that gains in malaria control could be maintained despite an increase in critical disease drivers (including temperature, humidity and rainfall).

Overall, the workshop provided a critical forum for the malaria research community to explore climate impacts, along with interventions and other variables, on the disease burden in Ethiopia.

Opening Session

Day 1:

April 28, 2014 9:00 am -12:30 pm

Chair of Morning: Wakgari Deressa, School of Public Health- AAU
Rapporteur of Morning: Barbara Platzer, Columbia Global Centers | Africa

Opening Remarks

Wakgari Deressa, School of Public Health- AAU

Dear colleagues and participants of the workshop,
Ladies and gentlemen:

On behalf of the School of Public Health at Addis Ababa University and myself, I would like to thank the organizers of the workshop for the opportunity to make this opening remark at this very important workshop on "Climate Variability and Change: Implications for Malaria Control and Elimination in Africa."

As you know, malaria is a major public health problem in Ethiopia, and it has been an impediment for the overall socio-economic development of the nation. Based on the country's health policy of prevention of communicable diseases, Ethiopia embarked on implementation of malaria prevention and control interventions in large scale since 2005. As a result, the malaria burden has significantly been reduced. Compared to the pre-intervention period 2005, malaria cases and deaths in recent years have declined by >50%. The aim of the malaria control program is towards elimination. Despite these important gains, malaria transmission is highly heterogeneous across the different parts of the country.

The effect of climate change on health is tremendous. Climate variability and changes influence the socio-economic development by affecting human health through extreme weather events and by bringing about changes in the ecology of infectious diseases. Malaria is a major climate sensitive public health problem, and it needs practical tools for predicting malaria epidemics based on weather and climate information. Such tools would be useful in making a more efficient use of the limited resources for malaria control. In this context, understanding the role of climate variability and change is very vital for the ultimate malaria elimination.

This workshop is therefore planned to contribute to the understanding of the implications of a changing climate for national malaria control and elimination strategies in Ethiopia. This will in turn help to identify opportunities for improving the *effectiveness of prevention, control and elimination strategies by incorporating an understanding of likely short and longer term changes in the climate in their analysis.*

This three-day workshop is convened by the School of Public Health at Addis Ababa University (SPH-AAU), the Ethiopian Public Health Institute (EPHI) and the Ethiopian Public Health Association (EPHA), with funding and technical support from the United States National Institutes of Health (NIH), the International Research Institute for Climate and Society (IRI), the Columbia Global Centers | Africa (CGC Africa) and the Health and Climate Foundation (HCF).

Ladies and gentlemen!
The SPH at AAU is very much pleased to be part of this very important workshop and hopes to strengthen the capacity of working together. The School is committed to provide any possible assistance for such type of workshop.

I would like to congratulate both partners from Ethiopia and the USA for the creative partnership they have developed together through the grant award from the National Institutes of Health. I understand that both partners have worked hard to materialize this workshop.

Finally, I would like to thank:

1. *School of Public Health at AAU*
2. *Ethiopian Public Health Institute*
3. *Ethiopian Public Health Association*
4. *National Institutes of Health*
5. *The International Research Institute for Climate and Society (IRI)*
6. *The Columbia Global Centers | Africa (CGC Africa) and*
7. *The Health and Climate Foundation (HCF).*

For their commitment for successfully organizing this important and timely workshop.
I hope the workshop will be a great success.

I wish you a fruitful and successful deliberation!

Thank you !

Madeleine Thomson, International Research Institute for Climate and Society

Dear colleagues, old friends and new,
Good Morning!

I am delighted to be back in Addis with my colleagues Rémi Cousin (IRI), Sylwia Trzaska (CIESIN) and Barbara Platzer (CGC Africa). We are excited to be able to spend the next three days with you all as we collectively address the challenge of understanding how climate drives malaria in Ethiopia and how its impact might be *felt in the coming months, years and decades. Most importantly we want to consider how this understanding can be translated into strengthened policies and practices that help prevent, control and even eliminate malaria in Ethiopia and elsewhere.*

As many of you are aware, IRI has been working for over a decade in the area of climate and health with a particular focus on Africa. We are a WHO Collaborating Center for Malaria Early Warning and Other Climate Sensitive Diseases and work with a wide range of stakeholders across a range of activities – from research, demonstration, education and training, advocacy and service. We are delighted to be working with the School of Public Health at Addis Ababa University and The Ethiopian Public Health Institute to deliver this workshop with the logistical support of the Ethiopian Public Health Association. We are of course thankful for the financial support from the US National Institute of Health who are funding this workshop and our partners including The Columbia Global Centers | Africa (CGC Africa) and the Health and Climate Foundation (HCF). We are also indebted to colleagues who have supported the development of the science and the materials we will be using in this workshop – Daniel Ruiz (IRI/Escuela de Ingenieria de Antioquia, Colombia) and Brad Lyon (IRI). Sadly they are unable to join us for the workshop but I am sure are here in spirit.

The motivation behind this workshop is based on the following observations. According to the most recent World Malaria Report malaria in East Africa has declined substantially since the turn of the century, when the Millennium Goals were first established. Over the same time period East Africa has experienced an increasing frequency of drought events particularly during the "long rains" season, which typically runs from March to May (Figure 1). Some climate scientists have argued that the increasing frequency of drought in East Africa is linked to an overall downward trend in East African rainfall which has been underway since the 1980s. Meanwhile, climate change projections, which use climate models to examine the potential effects of increasing concentrations of anthropogenic greenhouse gasses on the earth's climate, suggest that the climate of East Africa will become wetter by the end of the current century.

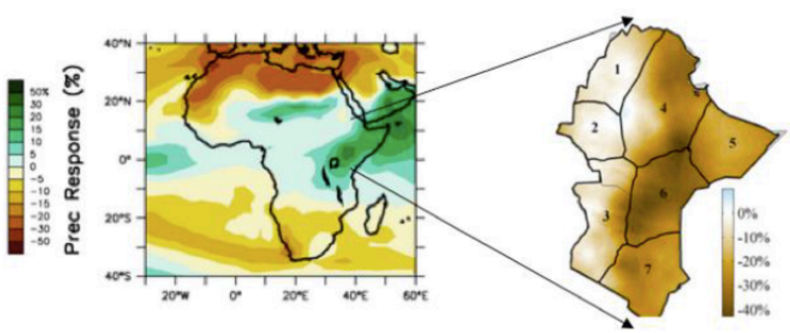

Figure 1. Left: Projected change in annual precipitation 2080-2099 relative to the observed climate 1980-1999 indicating a wetting trend. Obtained from IPCC Fourth Assessment Report Working Group I, Figure 11.2 (5). Right: Observed percentage change (drying) in long rains precipitation in the Greater Horn 1979-2009 relative to 1950-1979. Obtained from Williams and Funk, 2011, Figure 6 (1).

Still others argue that rather than a prolonged decline in rainfall since the 1980's, the long rains of East Africa have instead undergone an abrupt decline that occurred around 1998-99 and that it was associated with similarly abrupt changes in sea surface temperatures, mainly in the tropical Pacific.

This divergence in outcomes, between recent observations showing increasing drought and long-term climate projections suggesting conditions getting wetter, raises some fundamental questions to climate scientists and is a substantial challenge to policy makers and will be discussed during our workshop.

> *1. Can changes in climate in East Africa over the last decade help explain (among other issues) the current declines in malaria across the region and if so what proportion of the changes observed can be attributed to climate (versus other factors such as control)?*
>
> *2. What is the potential impact of future changes in climate in East Africa (due to natural variability and anthropogenic causes) on expected reductions in malaria as a result of current control or future elimination strategies?*
>
> *3. Given the importance of climate as a driver of malaria and the multiple time scales in which climate variability and change occurs – what are the key messages for policy makers if they are to make decisions informed by climate information?*

These are challenging questions. We are excited to have the chance to explore the answers with you through this workshop.

Hailegnaw Eshete, Ethiopian Public Health Association

Dear guests from:

- *International Research Institute for Climate & Society*
- *Columbia Global Centers | Africa*
- *National Meteorological Agency*
- *Distinguished participants*
- *Facilitators and coordinators of the workshop*
- *Ladies and Gentlemen,*

First of all, on behalf of EPHA, I would like to welcome you all to this Climate and Malaria modeling workshop.

Many of you here are already members of the Ethiopian Public Health Association (EPHA). For those that are new collaborators, EPHA is one of the leading and well-known health professional associations in Ethiopia with a current membership of over

4,000 professionals. Since its establishment in 1989, it has been working to promote better health services to the public and maintaining professional standards through active involvement, and networking that benefits its members, public health professionals, and the general public at large. Through the years the Association has significantly increased it membership and enhanced their technical capacity through training, conferences and its publications. It has also engaged in important and critical public health research areas of national and global interest and has provided the Ministry of Health and the health sector at large with evidence-based information and advice to influence policy, strategy and service delivery practices towards improving the quality and access of health services to the people of Ethiopia and achievements of the MDG.

EPHA is now pleased to continue its global collaboration with the Health and Climate Foundation, the IRI, Columbia Global-Center Africa, EPHI and the School of Public Health, Addis Ababa University to organize this important workshop. We are very much happy to collaborate with these institutions to work on one of our priority of public health issues. We would like to express our interest to continue our collaboration with these institutions for the successful implementation and expansion of Health and Climate initiatives across the region.

EPHA during its annual conferences gives special focus on malaria. During our recent 25th civil jubilee, a wide range of issues were presented on malaria control and elimination. I was very pleased to read abstracts and see the evidence using longitudinal data. Building on this, we are happy to facilitate this workshop. Also to add, a few years ago we also held the 13th World Congress on Public Health in Addis, with researchers from all of the world coming to Ethiopia to contribute to advances in public health research. I now look forward to learning more about the impacts of climate in Ethiopia, in malaria and in other sectors - both the challenges and opportunities.

We look forward to the recommendations from this workshop contributing to global health development efforts. We would like to thank all the organizing members for successful collaboration and continued support and wish the participants a productive meeting.

Let us of us to join hands for the better future implementation of Health and Climate collaborations. I wish you a successful deliberation. Thank you.

Background

Title: **Current Malaria Prevention, Control and Elimination Strategies in Ethiopia and their Sensitivity to Climate Variability and Change**
Speakers: Adugna Woyessa, EPHI

Malaria is a major public health problem in Ethiopia. Both altitude and climate determine endemicity and intensity of the disease. Thus, malaria is varying from place to place and from time to time due to high variability of these variables. Until the beginning of the 2000s, malaria epidemics have been the major manifestation of malaria epidemiology in the country. With the availability of global financial arrangements like Global Fund and effective intervention tools with the technical support from the World Health Organization/Roll Back Malaria and Global Malaria Control Program, malaria declined radically. This reduction includes sub-Saharan Africa, where most of the malaria burden is accounted for. Similarly, in the last decade, the malaria burden was reduced in Ethiopia following the large-scale application of key interventions (ACT, RDT, IRS and LLIN) since 2005. In 2007, WHO and other partners technically supported the launch of malaria elimination and eradication in endemic countries feasible for these strategies. Areas with low to moderate transmission were found to be eligible and eight countries were initially identified from Africa. In this context, Ethiopia embarked on a malaria elimination strategy by 2020. Since climatic factors play an important role in limiting malaria distribution, there is a need to see the impacts of high variability in climatic variables and its confounding effects. There is a need to differentiate or quantify the impacts of malaria interventions applied to meet targets apart from the confounding effects of climate variability. In order to sustain both local and global funding of the fight against malaria, this information is vital to national malaria control programs. Modeling tools technically sensitive enough to catch local malaria dynamics and those that are operationally feasible should be identified to help informed-decision. The elimination strategy considers local parameters unlike the control program that take the national issues as a priority in planning. Thus, interdisciplinary and cross-institutional collaborations are needed for a concerted effort in generating sounding evidence to influence policy. It is expected that this capacity building workshop will give us a direction and help design future collaboration at all levels.

Title: **Update on the Development and Use of ENACTS Rainfall and Temperature Products to Assess Climate Variability and Change in Ethiopia**
Speakers: Melesse Lemma and Jemal Gebeyehu, NMA

NMA in collaboration with the IRI has recently launched an effort to improve meteorological data availability, access and use. In the ENACTS project, NMA and IRI experts partnered to produce merged satellite-station data for every 4km grid across the country going back over 30 years. The conventional meteorological data observed at stations across Ethiopia were checked for quality and then merged with satellite derived rainfall and temperature data. Derived products have been made available through the Agency's website[1] and the gridded data are provided to users upon request.

This presentation provided an overview of the original project and current efforts to make gridded and merged data available to the wider user community. It also summarized who the current users of the data are. The first step in producing this

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[1] http://www.ethiometmaprooms.gov.et:8082/maproom/

data was identifying the gaps that exist in the conventional data sets. The next step was assuring the quality of the conventional rainfall and temperature data, followed by an interannual test of the data. Obtaining the satellite data by request was then a next step. The two data sets are then converted to the same spatial format and the merging is done. The combined rainfall dataset draws on more than 600 rain gauge stations merged with 30 years of satellite-derived rainfall estimates. For temperature, data from over 300 stations are combined with Moderate Resolution Imaging Spectroradiometer (MODIS) Satellite Land Surface Temperature (LST) estimates. NMA has recently reviewed users that have accessed both the online and offline data/information. The online Maprooms on the NMA website have been visited both within Ethiopia and abroad. The number of direct ENACTS data requests from governmental, academic and other institutions (in person at the Agency's head office) has reached 32.

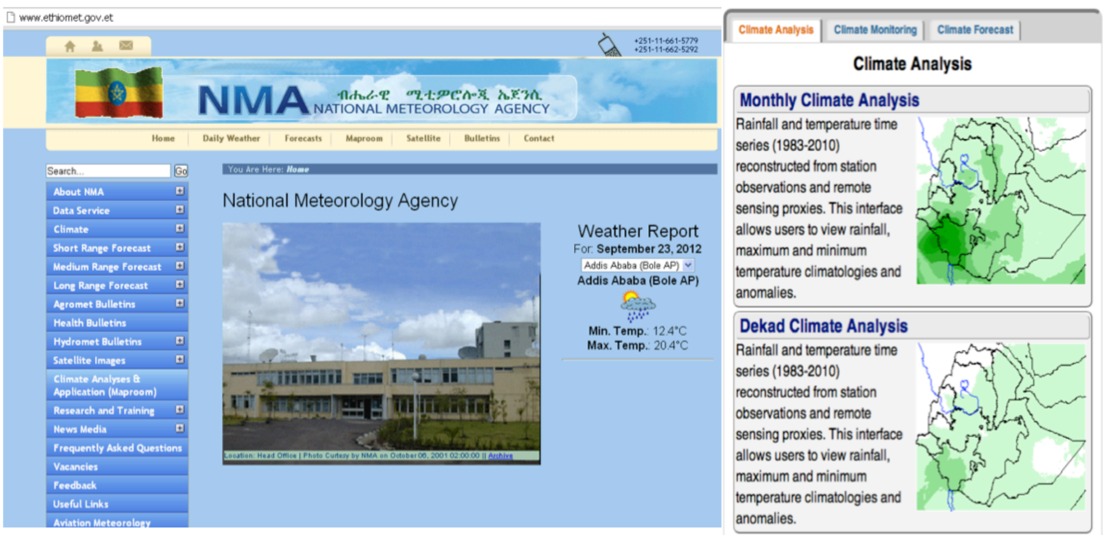

Figure 2. NMA's website and Maprooms.

Title: **Climate and Malaria – Key Concepts in Understanding Climate Risk to Malaria at Annual (ENSO), Decadal and Climate Change Time and Space Scales**
Speakers: Sylwia Trzaska, CIESIN

The presentation introduces a number of concepts central to the climate-malaria link to build a common knowledge and vocabulary base and facilitate further interactions between the climate and malaria communities. An important distinction is made between 'weather' (which operates on time–scales of days or shorter and presents great spatial variability) and 'climate' (which is a statistical characterization of weather over longer periods of time). However, climate is not a steady state and varies on a range of temporal and spatial scales, from one year to the next (interannual) to 10-20 year (decadal) shifts to longer-term trends linked to anthropogenic climate change.

In addition, longer-term changes in climate are relatively small compared to the amplitude of interannual to decadal variations. Longer-term changes in climate especially when estimated over periods shorter than a decade – typical for planning and evaluation – might be totally masked by interannual to decadal climate variations. For example, the drought conditions experienced in East Africa over recent years are in contradiction with the potential increase in rainfall in East Africa predicted in the IPCC report. However, they can be traced to specific decadal variations in Tropical Sea Surface Temperatures, as well to global rainfall anomalies patterns that had been observed in the past, highlighting that they might be linked to a recurrent and identifiable physical phenomenon in the climate system, independent of climate change. In addition, the well understood, monitored and predictable El Niño in the tropical Pacific occurring every 5-7 years has well documented impacts on temperature and rainfall in East Africa, factors of great importance to malaria.

The fact that climate varies on multiple time-scales is well illustrated from an analysis of rainfall in the Sahel over the last century (Figure 3).

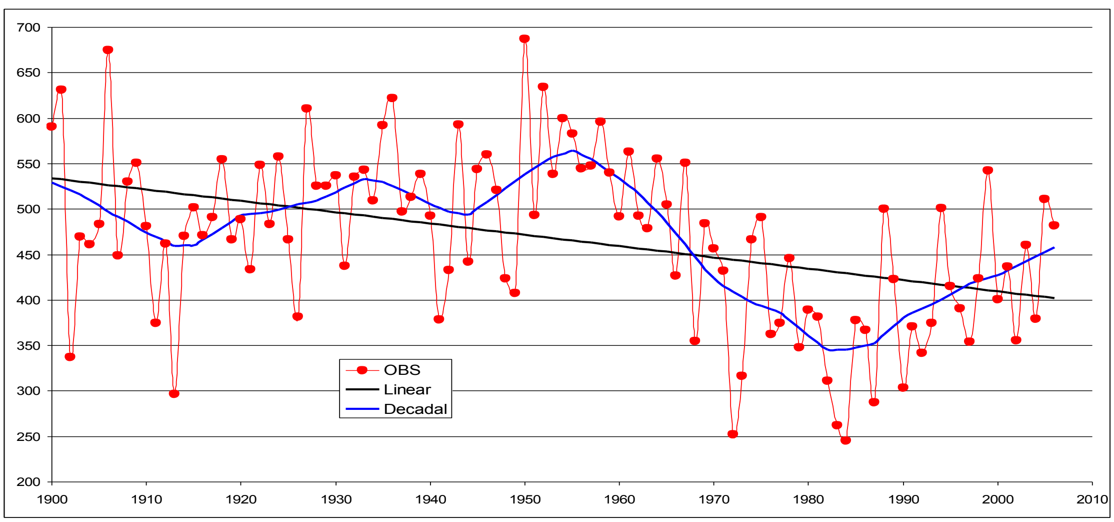

Figure 3. Observed annual rainfall in the Sahel over the period 1900-2006. This graph is based on a region-wide estimate of Sahelian rainfall over the last century. The black line is indicative of the long term trend in rainfall which accounts for less than 20% of the variance in the data. The blue line represents the slowly evolving shifts in the climate which occur at a decadal (10-20 year) time frame and which are driven by natural climate drivers. Nearly 30% of the variance in the data is captured by decadal variability. The red line represents year-to year (interannual) variability in the rainfall data, which accounts for more than 50% of the variance during the period of analysis.

Thus, despite the high priority of the climate change issue on the political agenda, it is interannual and decadal variations in climate that are most likely to have greatest impacts on malaria in coming years. In addition, they can also affect malaria control evaluations if the baseline or the follow-up evaluations coincide with anomalous climatic conditions impacting malaria rates, leading to over- or underestimations of intervention effectiveness.

A discussion of evidence of the impact of climate on malaria occurrence through changes in rainfall and temperature patterns follows based on papers focusing on Ethiopia (2), Kenya (3) and Botswana (4). Warmer than usual conditions projected for the future will most likely translate to increased malaria occurrence in the Ethiopian highlands, especially above 2000m which is currently considered the limit of transmission. For planning purposes, the impact of warmer temperatures can already be seen during ENSO events.

However, the establishment of strong evidence and assessments of past and potential future impacts of changes in malaria patterns in response to variations in climate is hampered by the lack of reliable, long-term climate and malaria data. The recent effort of the Ethiopian NMA to construct robust, high resolution rainfall and temperature datasets, that cover the entire country over 30 years, should facilitate some of the analyses. Building and communicating evidence of strong links between malaria (highland and lowland) and variations in climate, especially El Niño, is timely because of the potential occurrence of El Niño currently predicted for later this year.[2]

Photo 1. Sylwia Trzaska, CIESIN, presents on Enhanced Likelihood of El Niño This Year.

Questions and Discussions:

Key questions/items raised during the open Q&A following the morning presentations included:

- Participants were asked briefly if they were familiar with the Siraj et al. paper on altitudinal changes in malaria incidence in Colombia and Ethiopia. EPHI and PMI/USAID indicated they were aware of the publication.

- IRI inquired how NMA products might be used for seasonal forecasting and

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[2] http://iri.columbia.edu/our-expertise/climate/forecasts/enso/

ENSO. NMA indicated it used both the raw data and gridded ENACTS data for forecasting. For El Niño, NMA shared that conventional global data and sources are still consulted.

- PMI/USAID asked if longer term rainfall and temperature records could be accessed, e.g. in spreadsheets and not just through the online maprooms. NMA indicated that ENACTS is available online. For the provision of data itself, NMA clarified that this depends on those requesting it and their institutional affiliation and on the existing data policy. For some users, there may be a service charge payment. NMA indicated for researchers, there is no restriction for access.

- Earth Institute/Bioversity asked about the timing of when El Niño can be predicted and at what level this analysis is available? NMA indicated global sources provide authoritative consensus on likelihood of El Niño. CIESIN added that you start seeing signs in May-June and that by July-August high confidence can be put into predictions. CIESIN also elaborated that there is something called the 'spring barrier' in February-March and that before that it is too early for reliable El Niño predictions.

- SPH-AAU asked NMA about its data quality and credibility. NMA indicated there continue to be challenges with data quality and spatial resolution and known challenges with certain stations, etc. but that all historical and incoming real-time data are quality controlled (through a five-step process). CIESIN emphasized competence of Meteorological Services in knowing their own station data and that often users can benefit from dialog with Met Services on their analysis versus securing data on their own.

- Addis Continental asked about tailored information from NMA for the health community and how proactive NMA has been in reaching out not just to the research community. NMA clarified that its morning presentation on users was intended as a summary of users of the ENACTS products only, a relatively young data source, and that users of NMA climate services are much broader. NMA confirmed that MoH currently uses NMA data along with other ministries and sectoral users. NMA also indicated it has a focal point, Zerihun Bikili, that issues health and malaria bulletins. NMA did indicate that its most frequent users still come from agriculture, construction and research.

- SPH-AAU asked about micro-climates and local impacts of environmental changes. IRI provided as an example that they have had experience in East Shewa on an analysis of local environmental factors, such as changes in water bodies.

- IRI asked about the future policy landscape for malaria over the next five years. EPHI indicated that climate is an important concern, but that there are other factors as well that are significant for malaria control and elimination policy, e.g. drug resistance, commodities not being replaced (e.g. bed nets) and sustainability of interventions overall. PMI/USAID indicated importance of climate for impact assessments, for incorporation into analysis of scaled-up sentinel sites and for impact on migratory and labor movements. MoH reinforced need for evidence for national strategic plans and interventions moving forward, with climate being an important factor for policy and the work especially of the Emergency Response unit.

Summary of Technical Sessions

Day 1: Overview

April 28,20142:00 pm – 3:30pm

Chair of Afternoon: Henok Kebede, WHO Ethiopia, and Barbara Platzer, Columbia Global Centers | Africa
Rapporteur of Afternoon: Samson Wakuma, SPH-AAU

Title: **Using CPT as a Diagnostic Tool to Explore the Impact of Climate Variability and Change on Malaria**
Speakers: Sylwia Trzaska, CIESIN

The Climate Predictability Tool (CPT)[3] has been developed by climate scientists to facilitate tailored seasonal forecasting at scales relevant for decision makers (country, region etc.). It can be used as diagnostic tool to link various predictive variables (predictors) to variable(s) that need to be predicted (predictands). It can be further customized and adapted to the context of climate impacts on malaria.

The main objectives of this very quick introduction to CPT are to:

- Expose the participants to the tool and some of the methods suitable in the case of variables (predictors as well as predictands) that have large spatial and temporal dimensions, as it is often the case with climate variables.
- Provide the opportunity to manipulate simultaneously climate and malaria data with CPT used as diagnostic tool and explore relationships between climate variations on local versus regional and global scales.
- Expose participants to categorical and probabilistic approaches to prediction and related evaluation tools.
- Gather feedback on the potential of the tool to facilitate joint climate and malaria diseases and tool adaptation needed.

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[3] http://iri.columbia.edu/our-expertise/climate/tools/cpt/

CPT uses three methods to predict a climate (or other variable) outcome depending on the dimensions of the input and output variables. These are:

I. Standard multiple linear regression (MLR) with stepwise predictor selection in the case of univariate predictand and predictors;

II. Principal components regression (PCR) in the case of univariate predictand and multivariate predictors (e.g. with large spatio-temporal dimension) where the predictors are first reduced to principal components to avoid colinearity and reduce the dimension to a few interpretable components as predictors;

III. Canonical Component Analysis (CCA) when both predictand and predictors are highly multi-dimensional (e.g. time series of large spatial fields) and dimension reduction as well as orthogonality of the predictors and predictands prior to forecast are desirable.

CPT allows retrospective forecasts using cross-validation as well as independent training/hindcast period techniques. An extended set of forecast skill evaluations, both for continuous and categorical approaches, are automatically provided as well as a number of visualization options. Examples of use of CPT as a diagnostic tool linking malaria indicators to climate variables such as local rainfall as well as global Sea Surface Temperatures are provided.

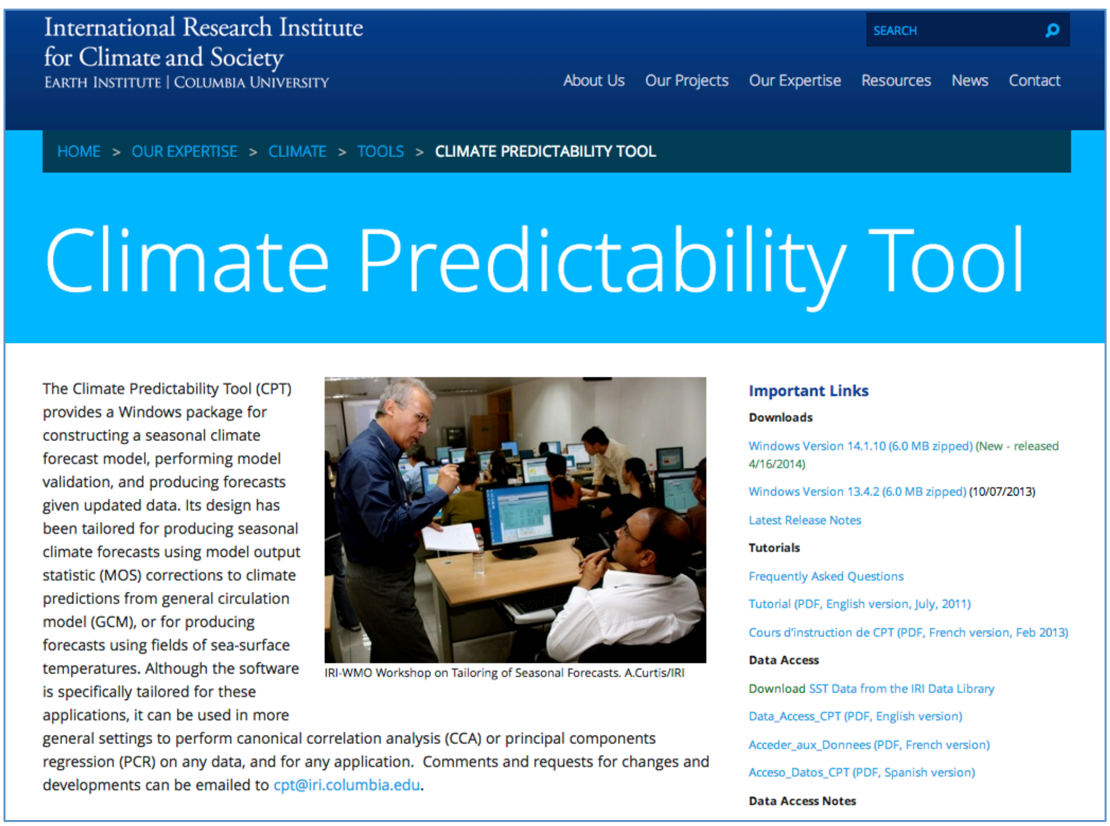

Figure 4. IRI Climate Predictability Tool website

Title: **Using a Multi-Model Malaria Platform to Explore the Impact of Climate Variability and Change**
Speakers: Madeleine Thomson, IRI

Dynamical models have played a significant role in understanding the complexity of malaria transmission dynamics since the discovery of the malaria transmission pathway by Ronald Ross at the turn of the 20th century. In this conceptual lecture, the importance of malaria process-based models in the context of malaria control will be discussed.

Some basic principles for model development include **Ockham's razor** a principle of parsimony, economy, or succinctness used in problem-solving devised by William of Ockham (c. 1287 - 1347).

Three sources of uncertainty in model development are considered:

- (i) Data quality – both in terms of predictands and predictors.
- (ii) Initial conditions – specifically the gametocyte carrier rate.
- (iii) Parameterization – using the example of the impact of model choice on the relationship between infectious mosquitoes and temperature.

The structure of a number of malaria process-based models will be explained as will the rationale for the use of a multi-model platform. This is based on lessons learned from experience in the climate community who note that because of the chaotic nature of the atmosphere, seasonal forecasts are necessarily probabilistic. These probabilistic predictions are defined from multiple integrations of deterministic climate models in which initial conditions are also varied. Multi-model systems have been found to be superior to any individual model system in terms of skill and potential economic value.

We will discuss current and future capabilities of the multi-malaria model platform (MMMP) based on a series of malaria dynamical models and consider its relevance in understanding malaria transmission complexity, estimating the timing and severity of epidemics, analyzing the role of key variables, pose and answer what if questions, investigate current decision-making processes and make quantitative goals for effective interventions, help decision-makers learn and undertake experimentation, analysis and verification.

Lastly, we will present the simulation outputs of four dynamical models (the MAC, AM, WCT, and ABP models) for the case of a pilot site in the highlands of Western Kenya.

Questions and Discussions:

Key questions/items raised following the afternoon presentations included:

- PMI/USAID asked how many years of data are generally required for prediction. CIESIN suggested that for good climate forecasting, longer data is needed- preferably 30 years. CIESIN indicated that in a recent climate and malaria analysis in Ethiopia data over five years were used, but results were limited.

- SPH-AAU inquired about how to take additional factors into account beyond climate such as late epidemic outbreaks and infection, use of traditional medicine and laboratory quality in modeling. CIESIN indicated that CPT looks only at temperature and rainfall and can't explain or forecast impact beyond these parameters.

- ACIPH asked if it is possible to use individual data for modeling. CIESIN indicated that there are models developed for individual data but models need to be informed about it.

- SPH-AAU asked about assumptions used in principal regression modeling. CIESIN emphasized that it was important to often use fewer and the most appropriate predictors, rather than many. In addition, CIESIN elaborated the following rules of thumb: to use multiple linear regression when predicators and predictands are unidimensional (simple time series), PC regression when the predictand is a time series and predictors a time series of spatial fields, and CCA modeling for multiple-scale analyses.

- MOH asked about forecasting when the size of data available for training the model is limited: e.g. a few years of malaria records. CIESIN suggested that if only annual or seasonal records are available the records might be too short to build a skillful model; on the other hand if these are weekly data and if weekly climate data were available and weekly output desirable, then even with a few years there might be enough information to build a skillful model. One needs to be careful however not to artificially increase the skill by modeling the full year when variables have a strong seasonal cycle, as prediction of the seasonal cycle should be skillful and contribute substantially to the overall skill of the forecast. Only the season of interest (e.g. malaria season) should then be used. With 12 weeks per season (or more if season is longer) there should be enough data points to inform the model even with a few years.

- IRI offered that most climate prediction tools are used widely by climate scientists, but that they are not designed per se for sectoral users. These types of tools are often powerful, but need to be modified for use by the health research community.

April 28, 2014 3:45 pm – 5:00 pm

Day 1: Quiz

Participants were given a short quiz to respond to after the coffee break (included in the appendix) to better understand their grasp of topics covered and materials presented. A recap of results were presented on Day 2.

Day 1: Moderated Discussion

A moderated discussion was facilitated by Madeleine Thomson, IRI, on the use of new data and tools to investigate the relationship of malaria to climate drivers in Ethiopia. Key items raised included:

- MOH thanked both presenters for their helpful presentations and inquired how policy makers and communities can use CPT and how it can be simplified for these audiences. IRI indicated this was a critical issue and said that it was often a "difficult thing to make things easy." IRI indicated that the tool and, modeling in general, was a way of investigating complex information that can inform community and policy decisions, but that it was a research tool and not intended as a tool for use by local communities.

- PMI/USAID asked how climate information could be used for annual planning. IRI indicated that ENACTS historical information, seasonal forecasting and El Niño signals could help to inform interventions and national strategy. CIESIN added that some decisions can benefit from climate information, but not all.

- MOH asked about the possible explanation for an absence of seasonal malaria outbreaks in Ethiopia in the last ten years. CIESIN suggested that several factors could be at play, both interventions but also recent drying trends in East Africa. IRI reinforced that when it is dry, it is less favorable for mosquito breeding. This year, when there might be an El Niño, temperature and rainfall will likely be impacted and may create a conducive environment for malaria epidemics in some regions, so it will be a big test if the interventions are working.

- MOH indicated that they have revised their malaria strategy from seven strata to four strata. The new strategies are based on evidence-based planning, more efficient allocation of resources and interventions appropriate to local level. The new strategies also consider additional factors other than elevation, rainfall and temperature.

- IRI asked MOH if Ethiopia uses seasonal chemoprophylaxis for malaria prevention. FMOH indicated that they do not use seasonal chemoprophylaxis. IRI gave the example of West Africa, where they treat children with chemoprophylaxis just at the beginning of the rainy season, so information on onset of the rains is important. There is now an agreement with a climate center predominantly responsible for food security based in Niger to provide this high quality rainfall and satellite data for improved chemoprophylaxis assessment.

- PMI/USAID mentioned the new malaria strategies include many interventions that will be implemented at different levels, so that it is very important to consider climate data and variability in the evaluation and impact assessments.

- MOH indicated that they have not traditionally used climate factors for malaria control with the exception of altitude. IRI commented that altitude is a proxy for temperature. When using altitude, we are really talking about colder highlands and hotter lowlands.

- After a request for feedback on Day 1, participants from SPH and ACIPH indicated some concepts were new and others more familiar. The importance of using climate information for health outcomes beyond malaria was also raised. Another participant from SPH indicated that most models in Ethiopia are statistical and not biological models and that linear model is not the most appropriate for malaria, which is affected by numerous, diverse factors. The complexity of modeling malaria in Ethiopia was elaborated on, along with the fact that models may need to be adapted to local conditions and not treated with one size fits all.

- IRI closed by reinforcing the availability of climate data in Ethiopia as a promising development for future malaria prediction.

Photo 2. Hiwot Solomon (FMoH), Henok Kebede (WHO Ethiopia), Samson Wakuma (SPH-AAU) and Wondimu Ayele (SPH-AAU) react to moderated discussion.

Day 2: Hands-On Training on the Climate Prediction Tool

April 29,20149:00 am -12:30 pm

Chair of Morning: Melesse Lemma, NMA
Rapporteur of Morning: Barbara Platzer, Columbia Global Centers | Africa

In the morning of Day 2, Sylwia Trzaska, CIESIN, presented results of the quiz highlighting questions that participants had difficulty answering correctly. The Climate and CPT sections presented the most challenges and the following items were discussed:

- The group reviewed Question 6 in particular on the amplitude of climate change rainfall and temperature signals over East Africa compared to climate variability, over the next 10-30 years. CIESIN elaborated that interannual and decadal climate variabilities relative to climate change trends are greater.

- The group also discussed the distinction between weather and climate and the different interpretations between user groups. CIESIN elaborated that weather forecasting has been around much longer and is a way of describing current and expected conditions over the coming days. CIESIN further reinforced that climate, on the other hand, is the average of observed weather over a longer time period to categorize what is 'normal'. NMA added that weather is meteorologically what is happening now and that climate is the average weather and includes variability and extremes.

- CIESIN also discussed the rationale behind using a large and small number of predictors in climate analysis and the danger of a false positive with using too many predictors. Also discussed the difference between use of predictors when analyzing large-scale climate impacts and small-scale, local climate phenomena. Participants asked about the rationale behind this, given that normally the more data points the better. CIESIN further cautioned about the danger of extrapolating from a single data grid point.

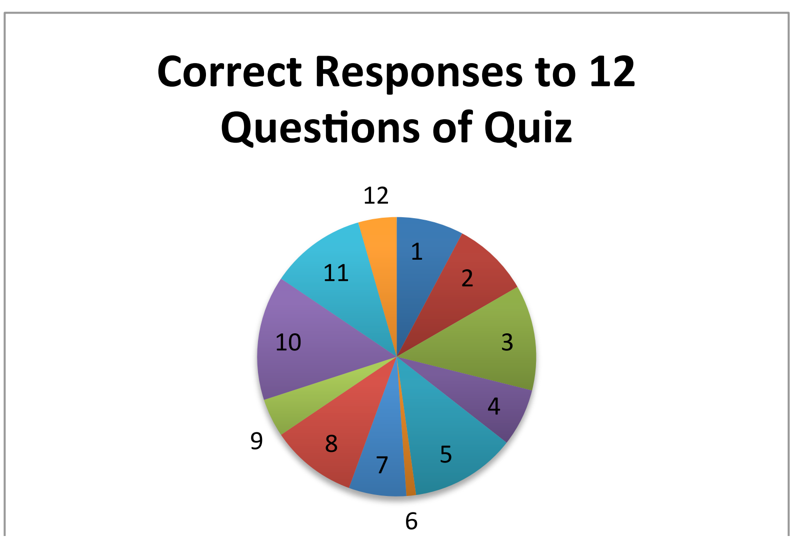

Figure 5. Results of correct responses to quiz for 12 questions given. 15 participants completed the survey. Question 6 presented the most difficulty, as nearly all participants mistakenly indicated that climate change trends were large relatively to short term variability.

Question 6 is included here (with correct response in bold):

The amplitude of Climate Change rainfall and temperature signals over East Africa compared to climate variability, over the next 10-30 years is:

1. **small to very small**
2. about the same
3. large
4. unknown

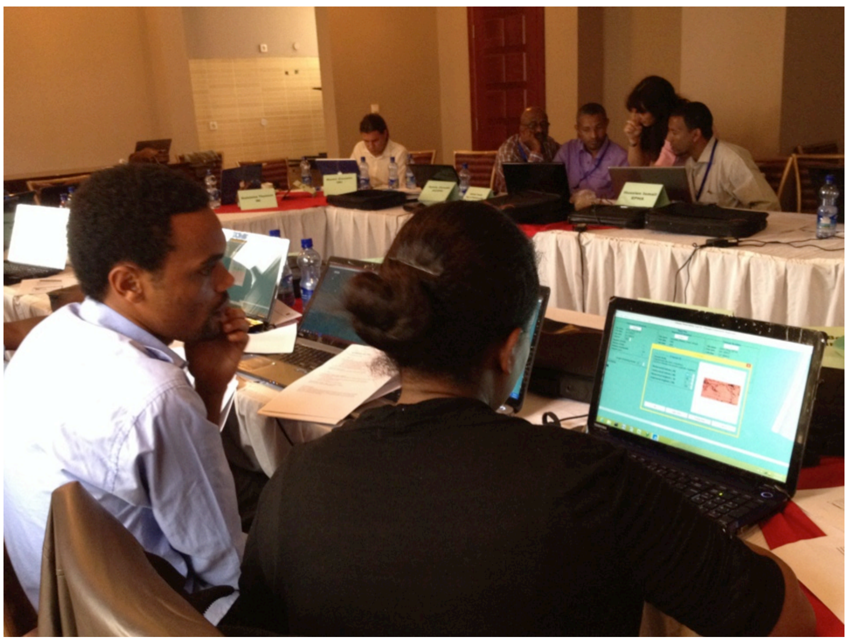

Photo 3. Participants test the Climate Predictability Tool.

Practical Exercises and Training:

During this session, participants were guided through practical exercises using CPT for malaria analysis in Botswana and Kenya. The session was led by Sylwia Trzaska, CIESIN. Madeleine Thomson also presented briefly on regions of predictive skill for seasonal precipitation and on the background materials for Kericho, Kenya (a study based on localized conditions and trends with monthly data) and Botswana (a study based on national and annual data).

Groups performed CPT analysis on Kericho and Botswana data and presented various analyses, including scatter plots of observations and cross-validated hindcasts, hind-cast observations and cross-validated residuals to test for false predictions, etc. Figure 6 outlines results from the CPT Botswana exercise.

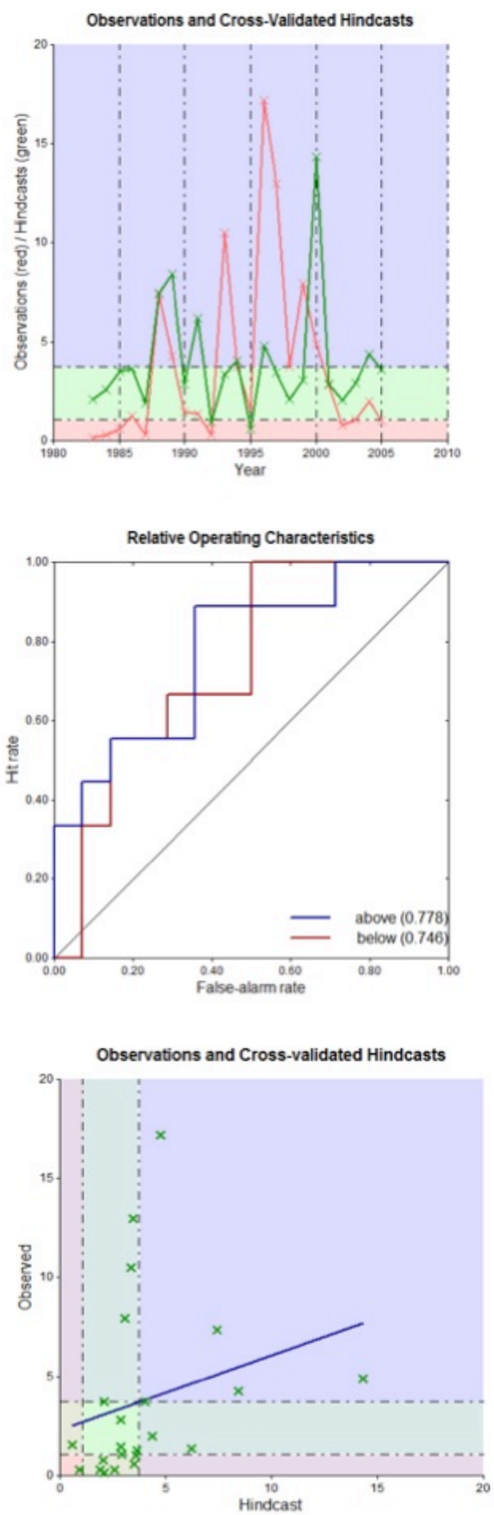

Figure 6. Results of the CPT Botswana exercise, including a) observed and cross-validated hindcasts of malaria incidence; b) observed and hindcast detrended malaria incidence; c) relative operating characteristics (ROC) analysis of a; d) ROC analysis of b; e) scatter plot of a; f) scatter plot of b.

Preliminary results from the CPT Kericho exercise are also included below.

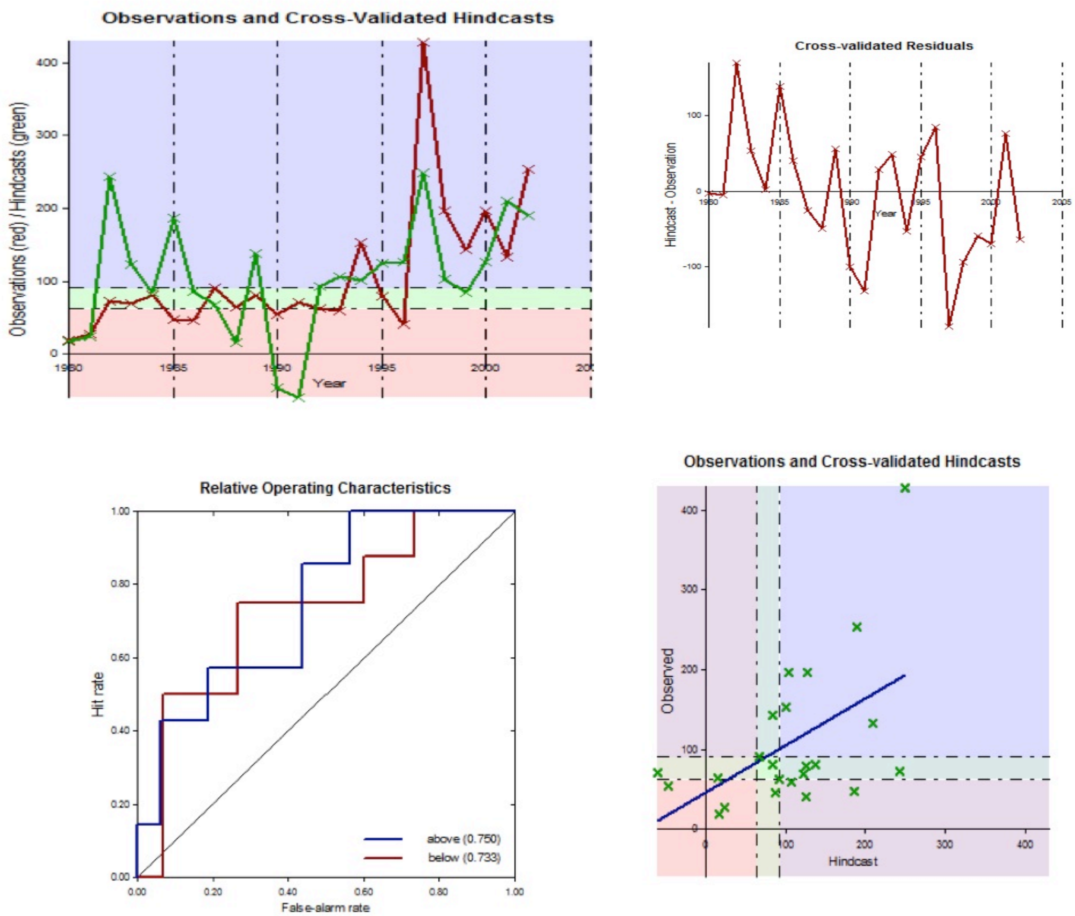

Figure 7. Results of the CPT Kericho exercise, including a) observed and cross validated hindcasts of malaria incidence; b) cross validated residuals; c) ROC analysis of a; d) scatter plot of a.

Day 2: Hands-On Training on the Multi-Model Malaria Platform

April 29, 2014 2:00 pm -5:00 pm

Chairs of Afternoon: Wakgari Deressa, School of Public Health- AAU, and Hiwot Teka, PMI/USAID
Rapporteur of Afternoon: Lelisa Sena, School of Public Health- AAU

Before moving to MMMP training and exercises in the afternoon of Day 2, Madeleine Thomson and Rémi Cousin provided a brief overview of the ENACTS website[4] and participants discussed the Map Rooms. The online platform developed currently

[4] http://www.ethiometmaprooms.gov.et:8082/maproom/

includes three Map Rooms for: Climate Analysis, Climate Monitoring, and Climate Forecast. The backup Maproom on the IRI site was used because the NMA Maproom was not functioning at the time of the exercise.

The Climate Analysis Map Room provides information on the mean climate (in terms of rainfall and temperatures)- at any location and averaged for Regions, Zones and Woredas. It can also show the performance of the rainfall/temperature seasons over the years as compared to the mean. The Climate Monitoring Map Room enables monitoring of the current season. Different maps and graphs compare the current season with the mean of recent years. This information could be extracted at any point or for any administrative boundary. Data is updated every ten days, thus enabling close monitoring of the season. Extracting and presenting information at any administrative level enables focusing on specific areas of interest. The Climate Forecast Map Room (Figure 8) translates the probabilistic seasonal forecasts to different values that can easily be understood by users. It presents the forecasts in the context of historical rainfall data and ENSO events. This information can be analyzed and extracted at sub-national levels.

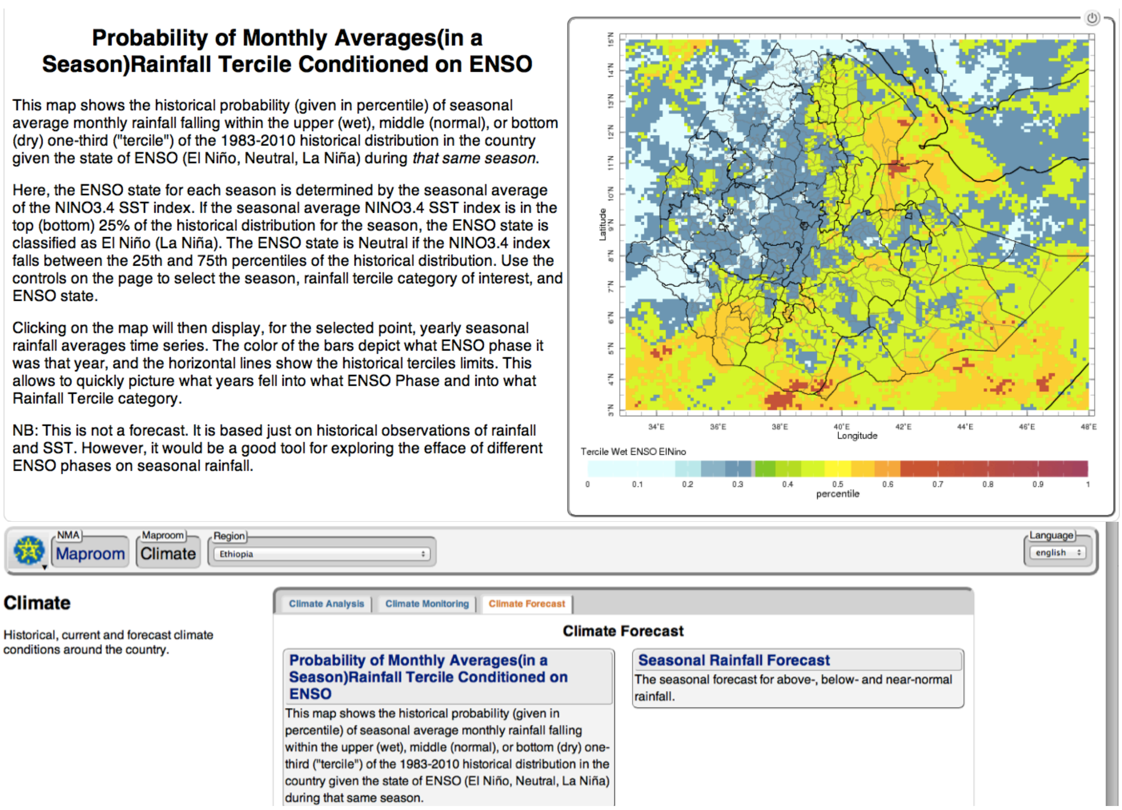

Figure 8. ENACTS Maproom with rainfall conditioned on ENSO.

Key items raised included the following:

- PMI/USAID questioned why rain for the month of August in one of the graphs was not visible as in other months? IRI replied that it could be the amount of rain is higher than would fit on the graph and this was a bug that was fixed in the official NMA version.

- IRI was asked about what the El Niño conditions in Ethiopia during dry/wet seasons would be according to the ENSO Map room? IRI demonstrated the web based Climate Forecast Maproom section and indicated that the probability affecting a part of the country could be estimated, depending of the season of focus.

- IRI reinforced that it is important to gain ownership and understand the different products and analyses through exercise and added requests.

- SPH asked about data formats and how the user can get the data in a way that is useful for their analysis? IRI & CIESIN replied that the software allows the user to extract data in most formats that are required. NMA may also be able to prepare the data in different formats, if requested.

- CGC Africa raised the issue of access to ENACTS and whether participants might get discouraged with site being down. Weakness of internet connection was complained about by participants. Recurrent power outages at NMA and throughout the city (e.g. larger infrastructure challenges) were discussed and absence of automatic process to restart the Maproom server. It was agreed some thought was needed to minimize the offline time.

Practical Exercises and Training:

In this practical session, Rémi Cousin, IRI, provided an online demonstration of the Multi-Malaria Model Platform (MMMP). This was followed by an investigation into the actual implementation of a four malaria-model ensemble for a specific malaria-prone pilot site: Kericho Tea Estate, in the highlands of Western Kenya. The ensemble was implemented to assess the impact of long-term changes in climatic conditions on *Plasmodium falciparum* malaria morbidity observed in Kericho over the period 1979-2009. Input data included quality controlled weather station records and near-surface and free air temperatures. Simulations included sensitivities to changes in sets of model parameters.

Using the same input and malaria morbidity data, it was clear that there were significant differences in the output from the four malaria models.

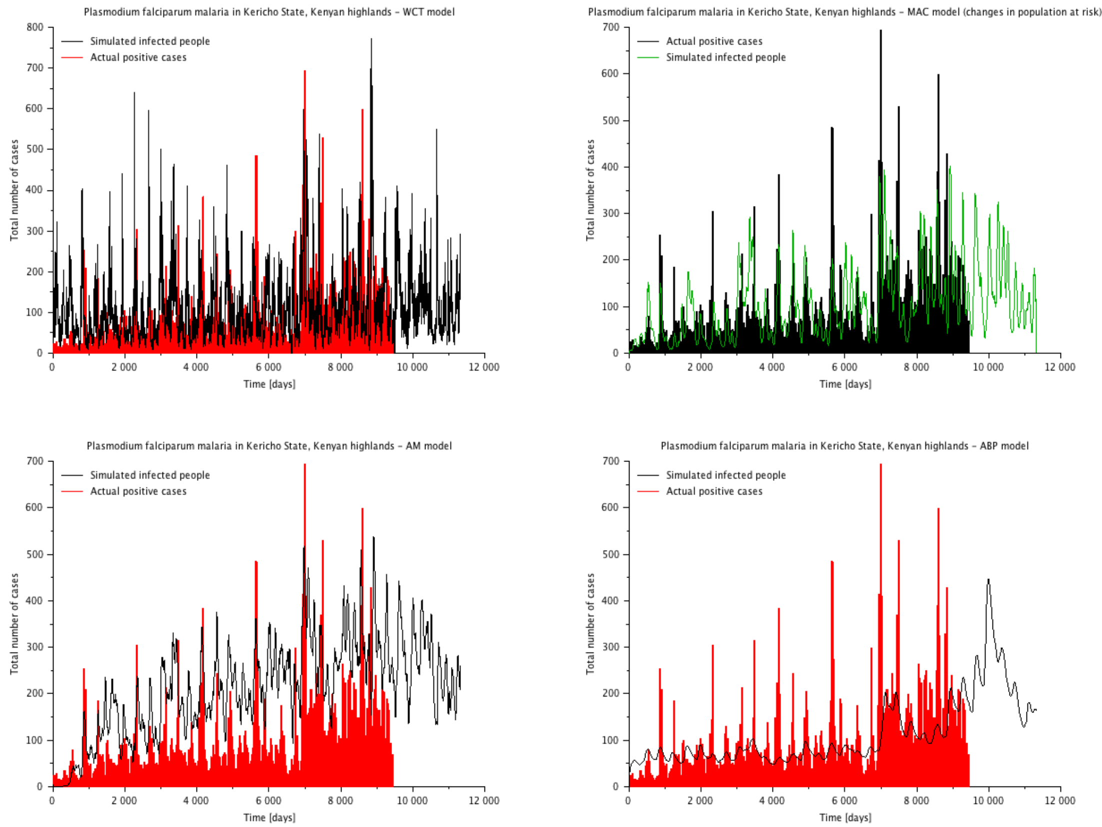

Figure 9. Malaria model outputs after parameterization and sensitivity analysis in Kericho, Kenya. Clockwise from top left: WCT, MAC, ABP and AM.

Questions and Discussions:

Key questions/items raised following this technical session included:

- The exercise was not easy for many of the participants. IRI adjusted the session to show the individual steps required, but this took longer than the allotted time.

- Graphs of different simulations from different models were displayed and participants asked which of the models best predicted epidemics of malaria. IRI indicated the choice of the model depended on individual needs, as different models are developed for different purposes. IRI further clarified that an understanding of what the different models are good at and how they work is important, with a careful statistical analysis assessing the skills of the models often required.

- IRI raised the idea that it could be important to quantify the variability of the forecasting models. A comparison of the model characteristics is needed considering some models are best at following seasonal and trend characteristics while others capture extreme events more effectively.

- IRI noted that dynamical models are parameterized to represent different components of the transmission process, given that interventions impact some of those components (e.g. IRS impacting life cycles of the mosquitoes or parasites), the models can help quantify the impact of interventions, through careful sensitivity analyses of the models to the parameters.

- PMI/USAID questioned which parameters are most important in the model. IRI responded that the literature can inform us on this, complemented by statistical tools which can aid us through sensitivity analysis of the models to small changes in the parameters.

Workshop Assignment:

At the end of Day 2, participants were given a brief assignment to reflect on before final recommendations were drafted during the Closing Session on Day 3.

Questions included:

1. Identification of additional (non-climatic) information for use in malaria modeling.
2. Policy implications of research results with focus on decision-making under uncertainty.
3. Recommendations for future research.

Feedback Session

April 30, 2014 9:00 am -12:00 pm

Chair of Morning: Adugna Woyessa, EPHI
Rapporteur of Afternoon: Samson Wakuma, SPH-AAU

Before proceeding with the break-out groups, Adugna Woyessa led a brief morning review of the assignment with a focus on the Siraj et al. article: *Altitudinal Changes in Malaria Incidence in Highlands of Ethiopia and Colombia.* Science, 2014. **343**(6175): p. 1154-1158.

- PMI/USAID gave a brief summary of the paper and participants gave some preliminary feedback on the article. The majority of the participants indicated agreement about the likely expansion of malaria in the highlands of Ethiopia in association with El Niño, although PMI/USAID raised potential data and laboratory quality problems and highlighted the low access to health services in Ethiopia, indicating it would be difficult to relate malaria epidemics in highlands of Ethiopia to climate change.

- Participants also discussed where malaria intervention should be targeted in the highlands, whether above 2000m sea level or above 2500m sea level. PMI/USAID suggested that the intervention should be 2000m above sea level and below, because of limited resources and to prioritize where the impact would be higher.

- CIESIN mentioned the importance of doing research on climate and malaria with large spatial coverage and longer time series. This type of research can serve as baseline data which will be important for monitoring.

Break-out Groups:

Sylwia Trzaska, CIESIN, facilitated the break-out group session, inviting participants into three smaller groups of 5 to 6. Each group was given a particular theme and targeted question:

- Malaria Evaluations (chaired by Hiwot Teka, PMI/USAID):
    - Given climate variations and changes, what needs to be done to improve malaria impacts assessments?
- Malaria Interventions (chaired by Adugna Woyessa, EPHI):
    - What is the potential impact of future variations and changes in climate in Ethiopia on expected reductions in malaria as a result of interventions?
- Engagement with Policy Makers (chaired by Wakgari Deressa, SPH-AAU):
    - Given the importance of climate as a driver of malaria, what are the ways we can engage policy makers most effectively?

Each group's discussion was structured around five themes: Research; Education and Training; Awareness and Advocacy (Key messages); Services; and Data (Climate, Malaria, Socio-economic, other) along with two time frames: the potential upcoming El Niño in 2014 and longer periods beyond the next year. The participants discussed their assignments for about 45 minutes and reported the main findings on each of them.

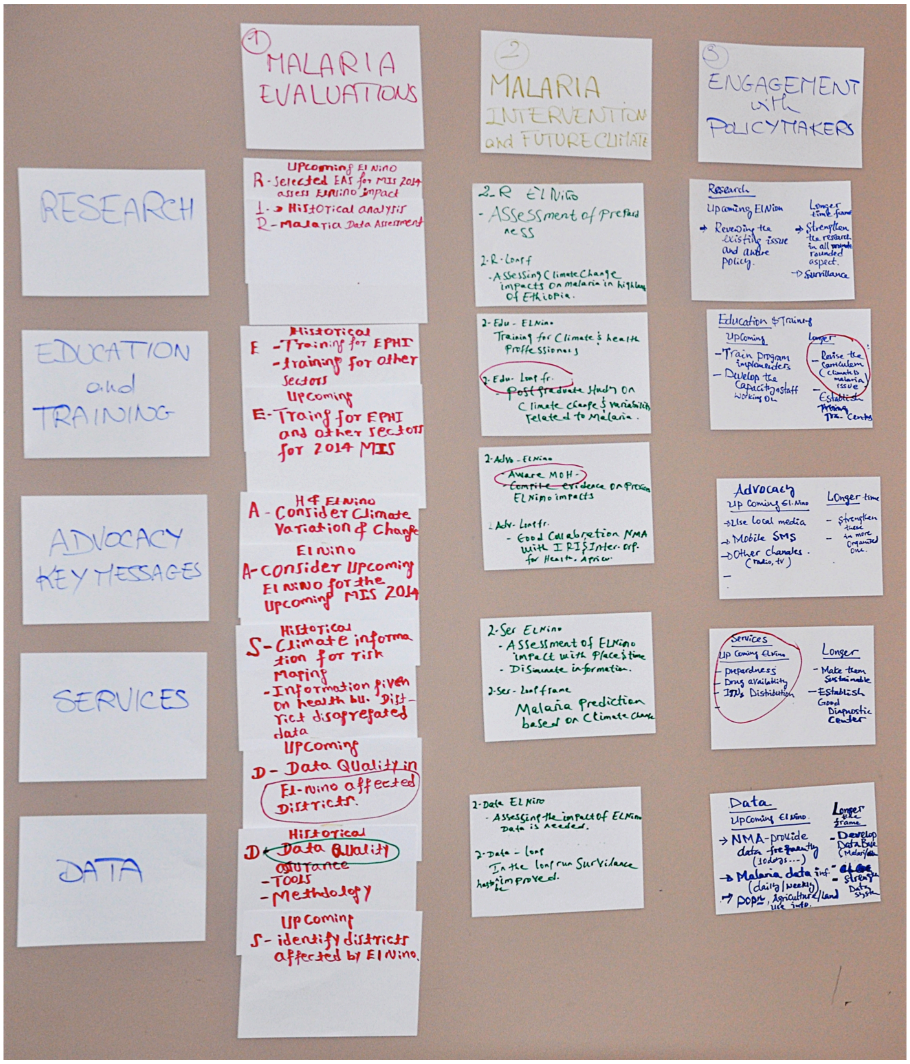

Photo 4. Draft recommendations presented by break-out groups during Feedback Session.

The group reconvened for a review and discussion of priorities where opportunities were given to contribute additional elements. The consensus priorities are captured in the recommendations, which reflect the structure of the discussions. The recommendations from the group were synthesized by a smaller committee during lunch break and presented for approval during the final afternoon session.

Closing Session

April 30, 2014 2:00 pm -3:30 pm

Chair of Afternoon: Madeleine Thomson, IRI
Rapporteur of Afternoon: Barbara Platzer, Columbia Global Center | Africa

Final Recommendations:

Below is a summary of final recommendation and identified next steps from the workshop, presented by Barbara Platzer (CGC Africa), and agreed by the participants.

A. *What are the priority activities going forward?*

	This Year	Next 3 years
Research	• Conduct follow-up survey on use of climate information by health sector at all levels. • Rapid assessment of awareness of El Niño in the health sector. • Use results of Malaria Indicator Survey and other instruments to assess impact of climate. • Desk review of impact of El Niño on malaria in previous years. • Create research team led by EPHI and NMA to investigate El Niño impact on health.	• Establish Climate and Health Collaborating Center. • Identify inter-sectoral research agenda (climate, water, nutrition, migration). • Build more evidence through research on climate-malaria • Engage national academic and research institutions
Education and Training	• Identify opportunities for targeted training for practitioners and implement with partners	• Formal climate and health curricula at the undergraduate & postgraduate level in SPHs. • Develop inter-sectoral collaborations/curricula between departments and schools. • Institutionalize climate in routine FMOH malariology, EPHI Training Center, FELTP programs.

Awareness and Advocacy (Key messages at policy, practitioner & community level)	• Policy brief on El Niño to FMoH, EPHI, NMCP, TAC with clear language on climate and impact uncertainties, opportunities and threats. • Updated advisories on El Niño with supporting evidence. • Routinely updated climate and health bulletins and briefings from NMA/EPHI.	• Incorporation of malaria and health outcomes in the broader climate & development agenda (e.g. PHE).
Services	• Identify districts most at risk of El Niño impacts. • Provide technical support to PHEM on emergency preparedness for El Niño. • Ensure routine access to ENACTS (in terms of infrastructure and protocols). • Ensure better information flow at all levels.	• Develop operational Early Warning Systems. • NMA to co-develop products tailored to sectors.
Data	• Assess available malaria data (morbidity and mortality) and explore methodologies for triangulation and incorporation in climate analysis. • Add additional parameters to ENACTS and lengthen time series.	• Improve monitoring systems, databases, data access and flow. • Demonstrate value of data through publications and use.

B. *What are key recommendations for improving and using the data and tools presented during the workshop (CPT, MMMP, ENACTS) and potential new products?*

1. Develop new products using ENACTS for El Niño preparedness.
2. Make ENACTS routinely available.
3. Use ENACTS in NMA malaria bulletin.
4. Test CPT and MMMP with Ethiopian data.

5. Identify opportunities for follow-up training (1-2 weeks) with tailored CPT and MMMP to Ethiopian context.

C. *What are key concrete next steps over the coming year?*

1. Participants to review and disseminate final workshop report and recommendations to their networks (May 2014).
2. EPHI, SPH-AAU, NMA and IRI to develop El Niño policy briefing (June-July 2014).
3. EPHI, SPH-AAU, NMA and partners to establish team focused on El Niño with agreed activity plan following workshop report and initial review (July 2014).
4. Present workshop outcomes at future international conferences (e.g. Healthy Future November 2014 meeting in Kigali, ASTMH).
5. EPHI, SPH-AAU and NMA led research team to explore publication with partner academic institutions (December 2014).

Closing Remarks:

Closing remarks were given by Adugna Woyessa (EPHI), Madeleine Thomson (IRI) and Wakgari Deressa (SPH-AAU).

Adugna Woyessa (EPHI) thanked participants for their feedback to the workshop, overwhelming contributions and recommendations for EPHI to consider. He indicated that outcomes of the workshop would help to guide EPHI in including climate their upcoming strategic plans and the Health Sector Development Program (HSDP), in place for twenty years and now going into its fifth iteration. Dr. Woyessa thanked IRI for its continuous support in sharing knowledge and technologies and keeping us aware of ongoing challenges and opportunities. He further indicated that he would share outcomes of the meeting with the MoH and closed by thanking long term partners SPH-AAU and NMA, new collaborators and the young researchers present.

Madeleine Thomson (IRI) also thanked the participants for their rich contributions and shared that, over the years, it was clear that the level of discussion has evolved on climate and health. She also cautioned that this year will be a big test for the climate, for malaria control and for ourselves in how effectively key messages can be communicated on climate impacts that are likely to be felt. She offered that the potential El Niño will present an exciting opportunity for those concerned with climate and malaria. She thanked the participants, colleagues from IRI and Columbia (both present and those back in New York and Colombia), the fellow organizing members and the host EPHA.

Wakgari Deressa (SPH-AAU) further added that the workshop provided the opportunity to learn a lot about the impacts of climate and newly available tools that could support country level malaria control and elimination strategies. He indicated that while the key partnerships have been in place, this was the first time for the organizing members to come together to prepare this type of workshop and expressed the hope that this network could also be leveraged to look beyond climate and malaria to other important health outcomes. He added that the meeting provided a great opportunity and platform to engage young researchers and thanked them for prioritizing their time and committing their energies. He also acknowledged all of the contributors behind the workshop and highlighted the many preparations taking place over the last few months. He concluded with explicitly thanking the Columbia team, EPHA, and EPHI, wishing participants a safe trip home, and then officially closed the meeting.

Appendix

Appendix 1: Agenda

Climate Variability and Change: Implications for Malaria Control and Elimination in Africa

Addis Ababa, Ethiopia

28 – 30 April 2014

Location: Siyonat Hotel, Bole

Day-1:

8:00-8:45

Registration

Opening Session

Chair of Morning: Wakgari Deressa, School of Public Health- AAU
Rapporteur of Morning: Barbara Platzer, Columbia Global Center-Africa

9:00-9:40

Official Welcome and Introductions

- Opening Remarks by Wakgari Deressa, School of Public Health- AAU
- Opening Remarks by Madeleine Thomson, IRI
- Opening Remarks by Hailegnaw Eshete, EPHA
- Introduction of Participants

9:40-10:40

Background

- Current Malaria Prevention, Control and Elimination Strategies in Ethiopia and their Sensitivity to Climate Variability and Change
(Adugna Woyessa, EPHI)

- Update on the Development and Use of ENACTS Rainfall and Temperature Products to Assess Climate Variability and Change in Ethiopia
(Melesse Lemma and Jemal Gebeyehu, NMA)

- Introductions to the Workshop
(Madeleine Thomson, IRI)

10:40-11.15
Group Photo & Coffee Break

11:15-12:00
- Climate and Malaria – Key Concepts in Understanding Climate Risk to Malaria at Annual (ENSO), Decadal and Climate Change Time and Space Scales
  (Sylwia Trzaska, CIESIN)

12:00-12:30
- Open Q&A on morning presentations.

12:30-2:00
Lunch

Technical Session: Overview

Chair of Afternoon: Henok Kebede, WHO Ethiopia, and Barbara Platzer, Columbia Global Center-Africa
Rapporteur of Afternoon: Samson Wakuma, SPH-AAU

2:00-3:30
- Using CPT as a Diagnostic Tool to Explore the Impact of Climate Variability and Change on Malaria
  (Sylwia Trzaska, CIESIN)
- Using a Multi-Model Malaria Platform to Explore the Impact of Climate Variability and Change
  (Madeleine Thomson, IRI)

3:30-3:45
Coffee Break

3:45-4:45
Quick Quiz

Moderated Discussion

- Madeleine Thomson, IRI, will facilitate group discussion on the use of new data and tools to investigate the relationship of malaria to climate drivers in Ethiopia.

4:45-5.00
- Wrap-up (Morning/Afternoon Chairs)

Day-2:

Technical Session: Hands-On Training on the Climate Prediction Tool (CPT)

Chair of Morning: Melesse Lemma, NMA
Rapporteur of Morning: Barbara Platzer, Columbia Global Center-Africa

9:00-12.30

- Review of Quiz
- Practical Training and Exercises Using CPT for Malaria Analysis in Botswana, Kenya and Ethiopia
  (Sylwia Trzaska, CIESIN, and Rémi Cousin, IRI)

12.30-2:00
Lunch

Technical Session: Hands-On Training on the Multi-Model Malaria Platform (MMMP)

Chair of Afternoon: Wakgari Deressa, SPH-AAU, and Hiwot Teka, PMI/USAID
Rapporteur of Afternoon: Lelisa Sena, SPH-AAU

2:00-4:30

- Online Demonstration of the Multi-Model Malaria Platform
  (Rémi Cousin, IRI, and Sylwia Trzaska, CIESIN)
- MMMP Practical Training and Exercises.

4:30-5:00

- Wrap-up & Assignment (Morning/Afternoon Chairs)

Assignment for Day 3: Introduced by Adugna Woyessa, EPHI

4. Identification of additional (non-climatic) information for use in malaria modeling.
5. Policy implications of research results with focus on decision-making under uncertainty.
6. Recommendations for future research.

Suggested Background Reading:

1. Siraj, A.S., et al., *Altitudinal Changes in Malaria Incidence in Highlands of Ethiopia and Colombia.* Science, 2014. **343**(6175): p. 1154-1158.
2. Thomson, M.C., et al., *Use of Rainfall and Sea Surface Temperature Monitoring for Malaria Early Warning in Botswana.* American Journal of Tropical Medicine and Hygeine, 2005. **73**(1): p. 214-221.
3. Omumbo, J., et al., *Raised Temperatures over the Kericho Tea Estates: Revisiting the Climate in the East African Highlands Malaria Debate.* Malaria Journal, 2011. **10:12**.

Day-3:

Feedback Session:

Chair of Morning: Adugna Woyessa, EPHI
Rapporteur of Morning: Samson Wakuma, SPH-AAU

9.00-10:30
Break-out Session:

Adugna Woyessa, EPHI, will provide recap of first two days of workshop and introduce break-out session. Small group discussions on:

- Assignment
- Feedback on Modeling Activities

10:30-11:00
Coffee Break

11.00-12:00
Group Feedback:

Session chair or nominated participant will collect findings from break-out groups and begin to identify recommendations.

12:00-2:00
Lunch

Closing Session:

Chair of Afternoon: Madeleine Thomson, IRI
Rapporteur of Afternoon: Barbara Platzer, Columbia Global Center-Africa

2:00-3:00
Hiwot Teka, PMI/USAID, and Barbara Platzer, CGC Africa, will present draft findings and recommendations from workshop, as well as identified next steps.

3:00-3:30
Closing Remarks by School of Public Health-AAU, EPHI, IRI.

Appendix 2: Participant List

No.	Last Name	First Name	Title/Role	Institute	Email	Gender
1	Tesema	Anteneh	Lecturer and PhD student (Biostatistics)	AAU, Department of Statistics	anteneh2123@gmail.com	M
2	Getachew	Atalay	MSc student	AAU, Ethiopian Institute of Water Resources	atalayget@gmail.com	F
3	Ayele	Wondimu	Lecturer	AAU, School of Public Health	wondaay@gmail.com	M
4	Beyene	Hunachew	PhD student	AAU, School of Public Health	hunachew@gmail.com	M
5	Deressa	Wakgari	Dean and Associate Professor	AAU, School of Public Health	deressaw@gmail.com	M
6	Getachew	Sefonias	Lecturer	AAU, School of Public Health	safoget@yahoo.com	M
7	Gezu	Meaza	Lecturer	AAU, School of Public Health	meaza.gezu@gmail.com	F
8	Gizaw	Muluken	Lecturer	AAU, School of Public Health	muluken.gizaw@yahoo.com	M
9	Sena	Lelisa	PhD student	AAU, School of Public Health	lelisajitu@gmail.com	M
10	Wakuma	Samson	Lecturer	AAU, School of Public Health	samson_wakuma@yahoo.com	M
11	Lemma	Seblewengel	Public Health Expert	Addis Continental Institute of Public Health	sebeye2007@gmail.com	F
12	Zewde	Ayele	Chief of Party SMMES Project	Addis Continental Institute of Public Health	ayelezewdew@gmail.com	M
13	Platzer	Barbara	Climate and Health Program Specialist	Columbia Global Centers | Africa	bplatzer@cgcafrica.org	F

14	Trzaska	Sylwia	Associate Research Scientist	Columbia University, Center for International Earth Science Information Network (CIESIN)	syl@ciesin.columbia.edu	F
15	Remans	Roseline	Associate Research Scientist	Columbia University, Earth Institute/Bioversity	rremanr@ei.columbia.edu	F
16	Cousin	Rémi	Senior Staff Associate	Columbia University, International Research Institute for Climate & Society	remic@iri.columbia.edu	M
17	Thomson	Madeleine	Senior Research Scientist	Columbia University, International Research Institute for Climate & Society	mthomson@iri.columbia.edu	F
18	Eshete	Hailegnaw	Executive Director	Ethiopian Public Health Assocation (EPHA)	h_eshete@yahoo.com	M
19	Ismail	Hussine	Operations Research and M&E Manager	Ethiopian Public Health Assocation (EPHA)	husnismail@yahoo.com	M
20	Seyoum	Dereje	Project Management Director	Ethiopian Public Health Assocation (EPHA)	dereje3@yahoo.co.uk	M
21	Solomon	Hiwot	Malaria Unit Focal Person	Federal Ministry of Health, Disease Prevention and Control	hiwisol2006@yahoo.com	F
22	Woyessa	Adugna	Malaria Epidemiologist	Federal Ministry of Health, Ethiopian Public Health Institute	adugnaf@yahoo.com	M
23	Gebeyehu	Jemal	Meteorologist	National Meteorological	jmlgeb@gmail.com	M

				Agency (NMA)		
24	Lemma	Melesse	Director, Met.Data & Climatology	National Meteorological Agency (NMA)	mellemma2001@gmail.com	M
25	Teka	Hiwot	Malaria Advisor	PMI-USAID Ethiopia	hteka@usaid.gov / hiwtek@yahoo.com	F
26	Kebede	Henok	Officer	WHO Ethiopia	henokk@et.afro.who.int hkejigu@gmail.com	M

Appendix 3: Workshop Organizing Institutions

Columbia Global Centers | Africa (CGC Africa)

Columbia Global Centers | Africa (CGC Africa) was launched in January 2012 and is supported by Columbia University in the City of New York. It represents the culmination of the University's impactful engagement with Africa spanning several years. The MDG Centre, the Earth Institute, the Mailman School of Public Health and the Graduate School of Architecture, Planning and Preservation, as examples, have been active in the region for many years, and close to 1000 Columbia alumni call Africa their home. CGC Africa is fast becoming a preeminent research and development organization in Africa providing thought leadership, cutting edge research, and expansion of scientific knowledge. It is one of eight global centers located in disparate locations around the world – Rio, Santiago, Beijing, Istanbul, Mumbai, Amman, Paris – linking Kenya and Africa to a to a vast body of knowledge, scholarship and enquiry, and providing an avenue for Africa to influence debates at the highest level. The Centre aims to:

- enable the highest levels of knowledge and learning in and for Africa;
- create a hub for global curriculum and scholarly outreach in Africa; and
- link the academic pursuits of the Global Center to Columbia's campuses in Morningside Heights and around the world.

Ethiopian Public Health Association (EPHA)

Established in 1989, the Ethiopian Public Health Association (EPHA) is one of the leading professional associations in Ethiopia with a total of over five thousand registered members. EPHA has actively engaged in partnering with government effort in promoting and streamlining the public health agenda in the country. EPHA envisions the attainment of the highest possible standard of health for all Ethiopians and its mission is to promote better health services for the public and maintain professional standards through advocacy, active community engagement and networking. The Association has 23 chapters located in the nine regions and two administrative cities of the country, with positions held in the public and private sector at all levels.

The Association has proven track records in strengthening professional skills and the capacity of its members through annual conferences, continuing education, and sponsorship of members to participate in international conferences, development of curricula, guidelines and research. Beyond its capacity building programs, EPHA also supports publications for generating and disseminating strategic information for decision making through the freely available *Ethiopian Journal of Health Development*, *Felege Tena Newsletter*, and *Public Health Digest/ the HIV/AIDS/STI/TB Bulletin*.

EPHA is a member of the World Federation of Public Health Associations (WFPHA). In 2008, EPHA was selected by the General Assembly of the WFPHA to host the 13th World Congress on Public Health on the theme of "Towards Global Health Equity:

Opportunities and Challenges". The Congress took place from April 23-27, 2012 in Addis Ababa and was concluded successfully. The EPHA secretariat also houses the recently established African Federation of Public Health Associations (AFPHA)and EPHA's president currently serves as secretary general for AFPHA. EPHA has prioritized work in several public health thematic areas, including HIV/AIDS, mental health, TB, malaria, environmental health and non-communicable diseases.

Ethiopian Public Health Institute (EPHI)

The Ethiopian Public Health Institute (EPHI) was recently established according to the Council of Ministers Regulation No. 301/2013 and launched on January 15, 2014, envisioned to support healthy, productive and prosperous Ethiopians. It was previously known as the Ethiopian Health and Nutrition Research Institute (EHNRI), established under the Regulation No.4/1996 following the merger of the former National Research Institute of Health (NRIH), the Ethiopian Nutrition Institute (ENI) and the Department of Traditional Medicine under the Ministry of Health. The mission of EPHI is to undertake research, based on the national public health agenda and priority health and nutrition problems, and to generate, absorb and disseminate scientific and technological knowledge to improve the health of the general public. EPHI is also mandated to produce vaccines for major infectious diseases and to improve the public health laboratory system at a national scale. In addition, EPHI is responsible for contributing to the national research agenda on public health and nutrition, conducting priority research, submitting policy briefs based on analysis and evidence, disseminating research findings and evaluating their impact, establishing a framework for the integration and effectiveness of research conducted throughout the country, putting in place a national research database, and providing assistance to regions and other entities conducting research.

Health and Climate Foundation (HCF)

The mission of HCF is to reduce health risks due to the impact of climate and of inequities in mitigation and adaptation strategies by facilitating and convening dialog and interaction between the health sector, climate services, research and development institutions, decision makers and community groups. The core values of HCF are to:

- Maintain a "facilitator" responsibility (avoiding substitution of institutional and managerial responsibilities);
- Ensure relevance of HCF support is related to public health impacts, especially to the most vulnerable;
- Support inclusiveness by helping ensure that partnerships have adequate composition with priority given to missing critical partners or disciplines;
- Focus on demand oriented services (information technologies, operational research, capacity building, training).

International Research Institute for Climate and Society (IRI)

The mission of the IRI is to enhance society's capability to understand, anticipate and manage the impacts of climate in order to improve human welfare and the environment, especially in developing countries. The IRI conducts this mission through strategic and applied research, education, capacity building, and by providing forecasts and information products with an emphasis on practical and verifiable utility and partnership.

The IRI was founded in 1997 on the belief that scientific breakthroughs in our understanding of climate can help developing countries defeat persistent and often devastating problems. Climate has an impact on health, water, agriculture and most other vital sectors, giving us the opportunity to help societies confront a whole range of hardships-from malaria epidemics to food shortages. Population growth, changing livelihoods, rapid urbanisation, and climate uncertainty put pressure on resources and ecosystems. Under these heightened stress conditions even minor climate fluctuations are significant.

The IRI is a catalyst for the creation and provision of scientific information that meets the needs of the developing world. We collaborate with partners in Africa, Asia and Latin America, with local institutions that understand local needs and capacity. Our research and tools are "demand-driven" in that they help solve specific development, adaptation and research management issues.

School of Public Health- Addis Ababa University (SPH-AAU)

The School of Public Health at Addis Ababa University (SPH-AAU) works towards advancing knowledge in public health that will contribute to the improvement of the health of individuals and populations in Ethiopia, East Africa and beyond. It is dedicated to the training of health professionals in public health; to the discovery, application and dissemination of new knowledge; and to the promotion of health and prevention of disease in communities and populations in collaboration with governmental, non-governmental and international agencies.

The SPH was upgraded from the then Department of Community Health in 2010 and is currently one of the four constituent Schools of the College of Health Sciences at AAU. It is primarily engaged in teaching graduate public programs and offers a PhD in public health and 10 different programs leading to Master's Degree. The School runs the Butajira Rural Health Program demographic surveillance site which is a field laboratory maintained since 1986.

Many national and international institutions such as John Hopkins Bloomberg School of Public Health (USA), University of Bergen (Norway), Umeå International School of Public Health (Sweden), University of Southern California (USA), Harvard School of Public Health (USA), MEASURE EVALUATION at North Carolina (USA), UNFPA, CDC and International Research Institute for Climate and Society (USA) choose to associate with SPH-AAU because of the experience of mutual learning through research and training.

Appendix 4: Quiz

Climate Variability and Change: Implications for Malaria Control and Elimination in Africa

Addis Ababa, Ethiopia

28 – 30April 2014

Correct answers are indicated in bold.

ENACTS

1. What climate variables are available in ENACTS?

- Precipitation, Average Temperature and Relative Humidity
- **Precipitation, Minimum Temperature and Maximum Temperature**
- Average Temperature, Minimum Temperature and Maximum Temperature
- Precipitation, Relative Humidity and Minimum Temperature

2. What is the time resolution of ENACTS data?

- **monthly**
- **10-daily**
- daily

3. Where can ENACTS information be viewed?

- World Meteorological Agency website
- **NMA website (Maproom)**
- IRI website – Data Library

Climate

4. When we talk about the impact of climate variability on malaria, we talk about:

- the weather, intern-annual variability, ENSO, decadal shifts
- **inter-annual variability, ENSO, decadal shifts, climate change**
- the weather, inter-annual variability, ENSO, climate change
- the weather, ENSO, decadal shifts, climate change

5. Why might El Niño events improve seasonal climate forecasts? Because:

- global tropic changes in temperature and precipitation over lands lags behind global tropic changes in sea surface temperature
- ENSO is the strongest sea surface temperatures signal in the world
- sea surface temperatures change more slowly than land climate variables
- **all are correct**

6. The amplitude of Climate Change rainfall and temperature signals over East Africa compared to climate variability, over the next 10-30 years is:

- **small to very small**
- about the same
- large
- unknown

Climate Predictability Tool

7. CPT was originally designed to:

- explore statistical relationships between variables
- make tailored malaria epidemic forecasts
- **make tailored seasonal climate forecasts**
- check data quality

8. CPT performs:

- dynamical modeling of climate phenomena
- **statistical analyses between predictors and predictands**
- dynamical modeling of malaria transmission
- data quality control, homogeneity checks and gap filling

9. Multiple linear regression (MLR), principal component regression (PCR) and canonical correlation analysis (CCA) are respectively appropriate for:

- **onepredictand and a small set of predictors, one predictand and a big set of predictors, multiple predictands and predictors**
- onepredictand and a big set of predictors, multiple predictands and predictors, one predictand and a small set of predictors
- multiplepredictands and predictors, one predictand and a small set of predictors, one predictand and a big set of predictors
- onepredictand and a small set of predictors, multiple predictands and predictors, one predictand and a big set of predictors

Multi-Malaria-Model Platform

10. Biological models are useful to:

- take into account non-linear relationships between climate and malaria cases variables
- identify and analyze key variables in the transmission process
- can be used to test hypotheses
- **all the above**

11. Sensitivity analysis allows one to:

- **identify key parameters in the transmission dynamics of malaria and therefore help design interventions**
- quantify the impact of future climate scenarios on transmission and therefore help design future policies
- identify what populations are more sensitive to malaria transmission and therefore help design nation-wide interventions
- assess what insecticides mosquitoes are more sensitive too and therefore help choose the right one

12. The advantage of climate-driven biological models over statistical models is that they alone can be used to:

- **Forecast the impact of interventions**
- Test the impact of multiple climate variables on malaria outcomes at the same time
- **Indicate a causal relationship between predictand and outcome**
- Model relationships of predictands and predictors at multiple time scales

Appendix 5: Training Materials

Climate Predictability Tool

Exercise 1: KERICHO case study based on the work of Omumbo et al. 2011 (3)

Multi Linear Regression

Using MLR and climate indices in file Kericho_Cx_data_OND make MLR cross validated retrospective forecast for Malaria DJF.

- Select the Response and explanatory variables and other analysis parameters
- Run the cross-validated analysis
- Explore the results
- Select two graphs for presentation

Principal Component Regression

Using PCR and SST_OND make cross validated retrospective forecast for Malaria DJF.

- Select the Response and explanatory variables and other analysis parameters
- Select 35N-35S and 20E-290 SST window for PCA
- Select other analysis parameters as appropriate
- Explore the results (including PC maps)
- Select two-three graphs for presentation
- Explore the sensitivity of the analysis to the SST window, include the conclusions in your presentation

Canonical Correlation Analysis

Using CCA explore predictability of the October – November – December (OND) rainfall over Ethiopia (ENACTS_OND_Precip in Climate folder) using OND SST.

- Select the Response and explanatory variables and other analysis parameters
- Run the cross-validated analysis
- Explore the results
- Select two-three graphs for presentation

Analysis for MAM season

Perform the above for the March-April-May (MAM) season.

Presentation

Prepare 5-6 slide presentation of the case study for OND season presenting the analyses and data used and examples of results; include most salient elements for MAM season analysis; include overall comments on the tool and your experience.

Exercise 2: BOTSWANA case study based on Thomson et al. 2005 (4)

Principal Component Regression

Raw malaria cases

1. Using PCR and DJF rainfall (GPCC_Prcp_DJF) make cross validated retrospective forecast for Annual Malaria Cases in Botswana (Raw).
   - Select the Response and explanatory variables and other analysis parameters
   - Select other analysis parameters as appropriate
   - Explore the results (including PC maps)
   - Select two-three graphs for presentation
2. Repeat the analysis using SST as explanatory variable

Detrended malaria cases

Repeat the analyses above for Detrended Annual Malaria Cases.

Canonical Correlation Analysis

Predictability of MAM rainfall in Ethiopia

Using CCA explore predictability of MAM rainfall over Ethiopia (ENACTS_MAM_Precip in Climate folder) using MAM SST.

- Select the Response and explanatory variables and other analysis parameters
- Run the cross-validated analysis
- Explore the results
- Select two-three graphs for presentation

Predictability of MAM or OND temperature in Ethiopia

Repeat the above analysis for temperature.

Presentation

Prepare 5-6 slide presentation of the case study for Botswana annual malaria cases presenting the analyses and data used and examples of results; compare results for raw and detrended Malaria data, comment; present a few results of climate predictability analysis; include overall comments on the tool and your experience.

Multi-Malaria Model Platform

Module I – Installing Scilab (the open source software for numerical computation) and running Scilab codes

1. Visit http://www.scilab.org/.
2. Download Scilab Version 5.5.0 (Windows 32 bits) onto your computer by clicking on the download link (a 127.09 MB file will be downloaded; at least 88.9 MB of free disk space is needed) or pick the appropriate system at http://www.scilab.org/download/5.5.0.
3. Run the Scilab setup wizard (scilab-5.5.0.exe) and install the full version (full installation).
4. Open the Scilab 5.5.0 console.

Module II – Running malaria process-based models in Scilab

1. Create a work folder and copy in the following files: databases (CDatasets2012-2.xls and Positivecases.xls) and codes (Datasets.sce, MAC2012.sce, AM2012.sce, WCT2012.sce, and ABP2012.sce).
2. Open the Datasets.sce file from the file browser window. Modify lines 1 and 4 of the Datasets.sce file by changing the path of databases files:

```
[fd1,SST1,Sheetnames1,Sheetpos1] = xls_open('C:\Your path here'); //Malaria total positive cases
[Cases,TextInd1] = xls_read(fd1,Sheetpos1(1));

[fd2,SST2,Sheetnames2,Sheetpos2] = xls_open('C:\Your path here'); //Climatic variables on daily timescale
[T,TextInd2] = xls_read(fd2,Sheetpos2(1));
```

3. Verify that all variables have been correctly uploaded in the variable browser.
4. Open the basic version of the Ross-Macdonald process-based model (MAC2012.sce)
    a. and run the code (Execute/Save and execute).
5. Qualitatively compare the results in the graphic window: actual positive cases are plotted in solid bars; infected individuals are plotted in solid line.
6. Repeat the process with the basic versions of the Anderson and May, Worral-Connor- Thomson and Alonso-Bouma-Pascual process based models (AM2012.sce, WCT2012.sce, and ABP2012.sce, respectively).

Module III – Understanding and interpreting simulation outputs – full certainty

1. In the SciNotes window, check the set of parameters of each process-based model. Note that parameters are fixed to fully-certain

representative values.

2. Quantitatively compare simulation outputs over the available retrospective period. For doing so use statistical parameters such as the correlation coefficient (R-value) between simulated malaria cases and actual positive cases, the percentage of the variance of the actual malaria morbidity that is explained by simulation outputs (R^2-value), the slope of the regression of simulated cases on actual cases (m-value), and the mean square and mean absolute errors (MSE).
3. Assess multi-model ensemble simulation runs using equally weighted models.
4. Assess models' sensitivities to small changes in sets of parameters.

Module IV – Understanding and interpreting simulation outputs under uncertainty (in model parameterization)

1. Modify parameters to several values within a sensible range reported in the literature.
2. Quantitatively compare simulation outputs using the R-value, R^2-value, m-value, and MSE for each set of parameters. If possible, include *functions of likelihood*, which allow us to assess the sets of parameters that yield comparable predictions of actual malaria positive cases.
3. Quantify the 25%, 50% and 95% percentiles of the distributions of simulated primary cases using all simulation outputs.
4. Use the 'most likely' models (with sets of parameters that yield 'comparable predictions') to assess the impacts of changes in climatic conditions on malaria transmission dynamics; i.e. run the models with and without long-term climatic trends, interannual dependency and historical seasonality.
5. Use the 'most likely' models to assess the impacts of changes in non-climatic variables such as the mean duration of host's infectivity to vectors (variable related to anti-malarial drugs resistance) and the probability of the mosquito surviving each gonotrophic cycle in a human population covered by an IRS campaign.

Module V – Thinking ahead

1. Run the 'most likely' models for short- to medium- to long-term changes in climatic conditions and non-climatic factors.
2. Assess multi-model ensemble simulation runs by assuming that tools with higher reliability should weigh more than those with lower skill level.

Appendix 6: Botswana and Kericho Data for Training Exercises

Botswana National Confirmed Malaria Data

Year	Malaria incidence per 1000[5]	Detrended malaria incidence[6]
1982	8.34E-02	-0.65
1983	0.15315	-0.46
1984	0.29527	-0.25
1985	0.56209	-0.04
1986	1.2476	0.23
1987	0.27454	-0.50
1988	7.3626	0.85
1989	4.2773	0.54
1990	1.4727	0.01
1991	1.3438	-0.11
1992	0.30547	-0.82
1993	10.506	0.64
1994	3.7455	0.12
1995	1.5571	-0.34
1996	17.17	0.63
1997	12.956	0.35
1998	3.7108	-0.11
1999	7.9554	0.31
2000	4.9075	0.18
2001	2.8057	0.03
2002	0.75754	-0.46
2003	1.0724	-0.22
2004	2.0082	0.14
2005	1.0031	-0.08

[5] Botswana National Malaria Cases per 1000 – available from a number of public sources

[6] Detrended* Anomalies of Malaria Cases per 1000 used in exercise. Note that a range of detrending methodologies exist (e.g. see Thomson et al., 2005). Here the detrended series consists of the residuals in a multiple regression model considering only the non-climate parameters only.

Kericho Data

Year-Mon	Estimated confirmed monthly malaria cases[7]
1979-01	25
1979-02	25
1979-03	20
1979-04	30
1979-05	18
1979-06	18
1979-07	15
1979-08	15
1979-09	10
1979-10	20
1979-11	35
1979-12	25
1980-01	25
1980-02	20
1980-03	20
1980-04	45
1980-05	55
1980-06	80
1980-07	55
1980-08	30
1980-09	25
1980-10	25
1980-11	20
1980-12	15
1981-01	20
1981-02	24
1981-03	20
1981-04	25
1981-05	255
1981-06	210
1981-07	70
1981-08	52
1981-09	30
1981-10	45
1981-11	50
1981-12	20
1982-01	30
1982-02	34
1982-03	40
1982-04	30
1982-05	48
1982-06	185
1982-07	70
1982-08	60
1982-09	65
1982-10	70
1982-11	54
1982-12	25
1983-01	95
1983-02	100
1983-03	70
1983-04	60
1983-05	55
1983-06	60
1983-07	52
1983-08	52
1983-09	48
1983-10	45
1983-11	40
1983-12	48
1984-01	70
1984-02	90
1984-03	65
1984-04	45
1984-05	90
1984-06	105
1984-07	92

[7] Estimated monthly malaria-positive cases from inpatient admission registers in Tea Plantation 1 in Kericho, spanning the period January 1970 to October 2004, were obtained from Figures 4 and 6 in Shanks et al., 2005 (reference 6).

1984-08	50
1984-09	60
1984-10	30
1984-11	30
1984-12	65
1985-01	65
1985-02	115
1985-03	35
1985-04	145
1985-05	305
1985-06	70
1985-07	68
1985-08	48
1985-09	48
1985-10	40
1985-11	30
1985-12	54
1986-01	40
1986-02	48
1986-03	50
1986-04	115
1986-05	130
1986-06	98
1986-07	105
1986-08	75
1986-09	50
1986-10	48

1986-11	52
1986-12	20
1987-01	48
1987-02	70
1987-03	95
1987-04	98
1987-05	90
1987-06	135
1987-07	85
1987-08	215
1987-09	65
1987-10	45
1987-11	55
1987-12	90
1988-01	105
1988-02	80
1988-03	75
1988-04	55
1988-05	90
1988-06	150
1988-07	315
1988-08	80
1988-09	78
1988-10	72
1988-11	68
1988-12	64
1989-01	74

1989-02	54
1989-03	45
1989-04	80
1989-05	30
1989-06	85
1989-07	140
1989-08	95
1989-09	60
1989-10	52
1989-11	45
1989-12	40
1990-01	55
1990-02	150
1990-03	80
1990-04	225
1990-05	385
1990-06	200
1990-07	80
1990-08	60
1990-09	55
1990-10	35
1990-11	25
1990-12	40
1991-01	65
1991-02	55
1991-03	90
1991-04	70

1991-05	140
1991-06	245
1991-07	100
1991-08	65
1991-09	65
1991-10	45
1991-11	65
1991-12	70
1992-01	75
1992-02	70
1992-03	45
1992-04	35
1992-05	150
1992-06	205
1992-07	165
1992-08	108
1992-09	80
1992-10	70
1992-11	40
1992-12	35
1993-01	70
1993-02	85
1993-03	110
1993-04	95
1993-05	75
1993-06	65
1993-07	110

1993-08	120
1993-09	90
1993-10	85
1993-11	75
1993-12	50
1994-01	55
1994-02	70
1994-03	85
1994-04	140
1994-05	185
1994-06	485
1994-07	275
1994-08	130
1994-09	100
1994-10	55
1994-11	40
1994-12	90
1995-01	190
1995-02	180
1995-03	80
1995-04	45
1995-05	65
1995-06	75
1995-07	105
1995-08	90
1995-09	55
1995-10	30

1995-11	50
1995-12	90
1996-01	80
1996-02	70
1996-03	73
1996-04	102
1996-05	175
1996-06	120
1996-07	110
1996-08	70
1996-09	45
1996-10	30
1996-11	25
1996-12	28
1997-01	36
1997-02	60
1997-03	48
1997-04	35
1997-05	68
1997-06	300
1997-07	110
1997-08	55
1997-09	35
1997-10	35
1997-11	55
1997-12	175
1998-01	415

1998-02	695
1998-03	410
1998-04	130
1998-05	155
1998-06	160
1998-07	170
1998-08	210
1998-09	130
1998-10	170
1998-11	180
1998-12	145
1999-01	245
1999-02	200
1999-03	200
1999-04	100
1999-05	370
1999-06	370
1999-07	530
1999-08	120
1999-09	95
1999-10	110
1999-11	110
1999-12	120
2000-01	140
2000-02	170
2000-03	200
2000-04	115

2000-05	160
2000-06	180
2000-07	150
2000-08	95
2000-09	110
2000-10	100
2000-11	105
2000-12	90
2001-01	265
2001-02	235
2001-03	225
2001-04	105
2001-05	105
2001-06	230
2001-07	240
2001-08	250
2001-09	165
2001-10	135
2001-11	225
2001-12	50
2002-01	210
2002-02	140
2002-03	150
2002-04	145
2002-05	250
2002-06	390
2002-07	600

2002-08	325
2002-09	190
2002-10	110
2002-11	170
2002-12	100
2003-01	330
2003-02	330
2003-03	430
2003-04	130
2003-05	190
2003-06	210
2003-07	240
2003-08	170
2003-09	130
2003-10	165
2003-11	110
2003-12	130
2004-01	210
2004-02	205
2004-03	205
2004-04	105
2004-05	190
2004-06	180
2004-07	165
2004-08	95
2004-09	95
2004-10	70

Appendix 7: References

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