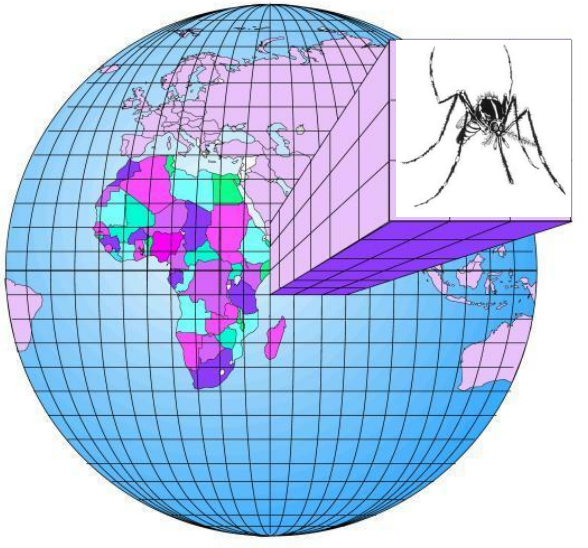
Modéliser l'impact du réchauffement climatique sur les maladies vectorielles



Dr C. Caminade

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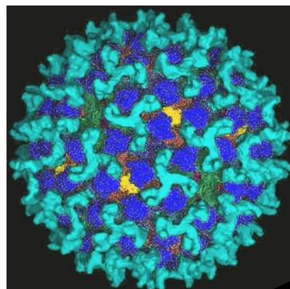
***Thanks to**: Dave MacLeod, Andy Heath, Andy Morse and Anne Jones, School of Environmental Sciences, University of Liverpool, Liverpool, U.K.; Matthew Baylis, Marie Mc Intyre, Kathy Kreppel, Daniel Impoinvil, Jan Van Dijk, Institute of Infection and Global Health, University of Liverpool; Jolyon Medlock and Steve Leach, Health Protection agency, Porton Down, UK; Helene Guis, CIRAD, Montpellier, France; Jacques Andre Ndione, CSE, Dakar, Senegal and many others I surely forgot...*

Vector Borne diseases

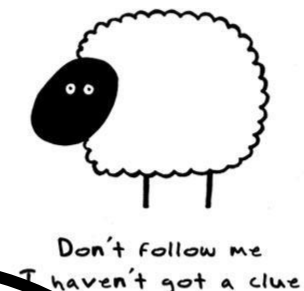
Diseases transmitted by blood sucking arthropods

Pathogen



- Survival
- Replication rate

Host



- Growth rate
- Survival
- Distribution
- Life habits

Vector

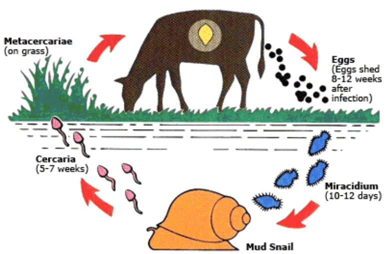
- Survival
- Development rate
- Activity
- Length of gonotrophic cycle
- Vector competence

Climate variability
Rainfall
Temperature
Humidity
Winds...

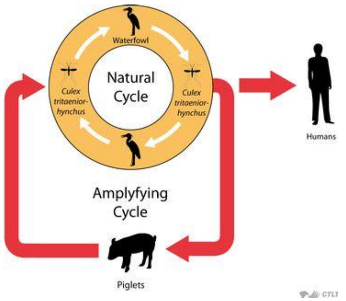
Modelling Disease risk based on climatic indicators:

Last 6 years in Liverpool...

Impact of climate upon **bluetongue** transmission in Europe.
Guis et al., 2012.



Impact of climate upon **liver fluke** in the UK GLOWORM EU project (in prep)



Japanese encephalitis. Impoinvil et al., 2011, 2013.

Malaria modelling. Seasonal forecasts & climate change scenarios Caminade et al., 2014b & 2014c.

Rift Valley Fever Caminade et al., 2011 & 2014a. work with J.A. Ndione

Mapping **Asian tiger mosquito** climatic suitability. Caminade et al. 2012, Work with the HPA

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Rift Valley Fever

Zoonosis generally transmitted by Aedes and Culex mosquitoes.

RVF virus is a member of the genus *Phlebovirus* (family Bunyaviridae).

Symptoms

Animal symptoms: high level of abortion in pregnant females, vomiting and diarrhoea, respiratory disease, fever, lethargy, anorexia and sudden death in young animals.
High mortality rate (especially in lamb, calf, sheep and goat).

Human symptoms: large fever, headache, myalgia
Can lead to hemorrhagic fever meningitis and death (<2%).
Low mortality rate.

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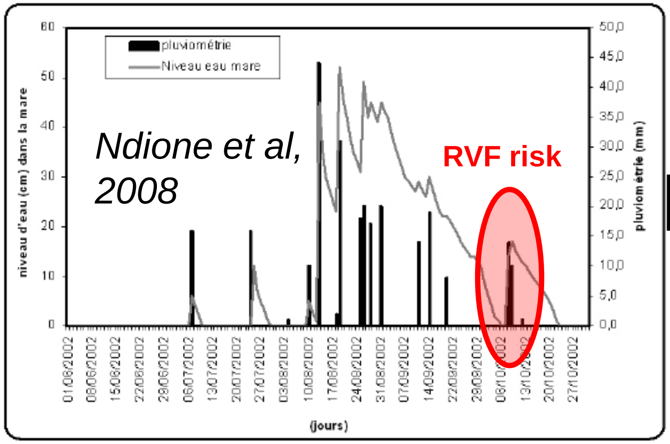
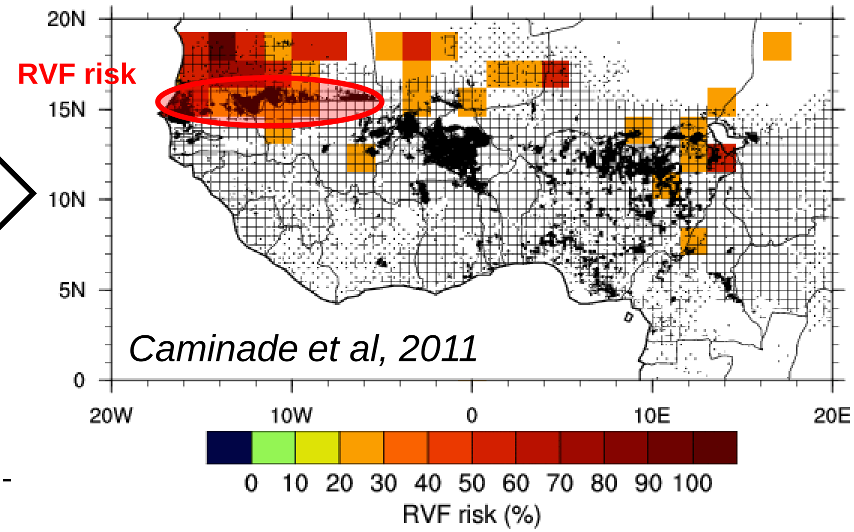
Rift Valley Fever & climate



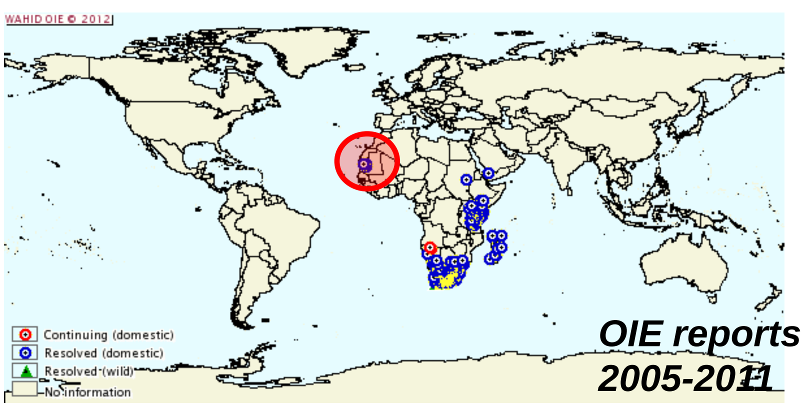


Dry spell followed by a rainfall peak during the late rainy season (Sep-Oct) over Northern Senegal (Ngao pond, Barkedji in 2002)

→ Rehydrating ponds

→ Culex and Aedes mosquitoes hatching + host promiscuity

→ high RVF risk



Countries with endemic disease and substantial outbreaks of RVF

Countries known to have some cases, periodic isolation of virus, or serologic evidence of RVF

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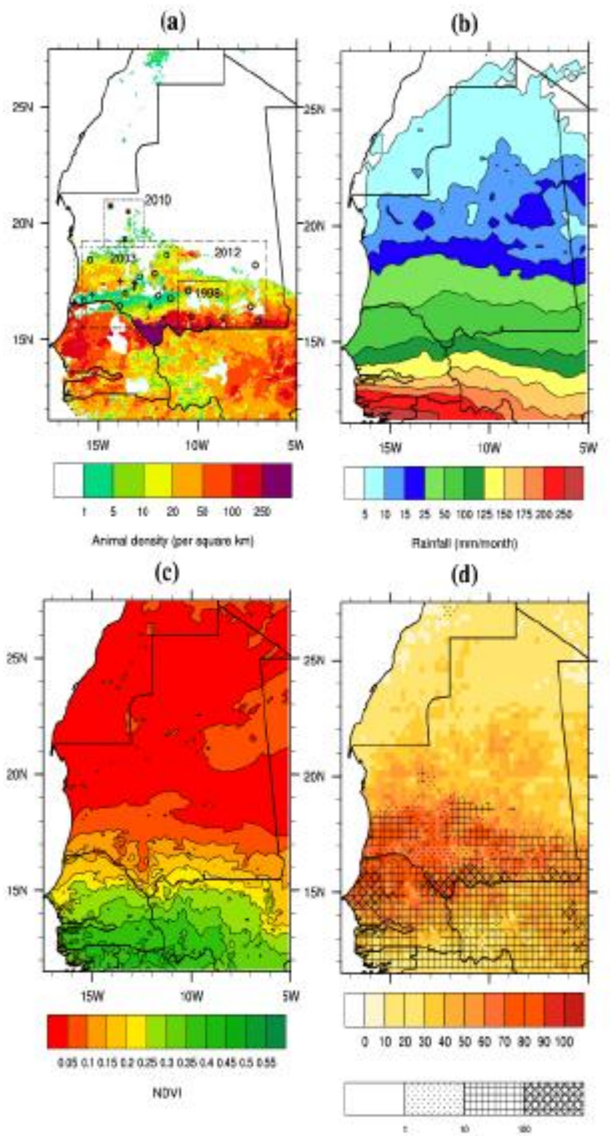
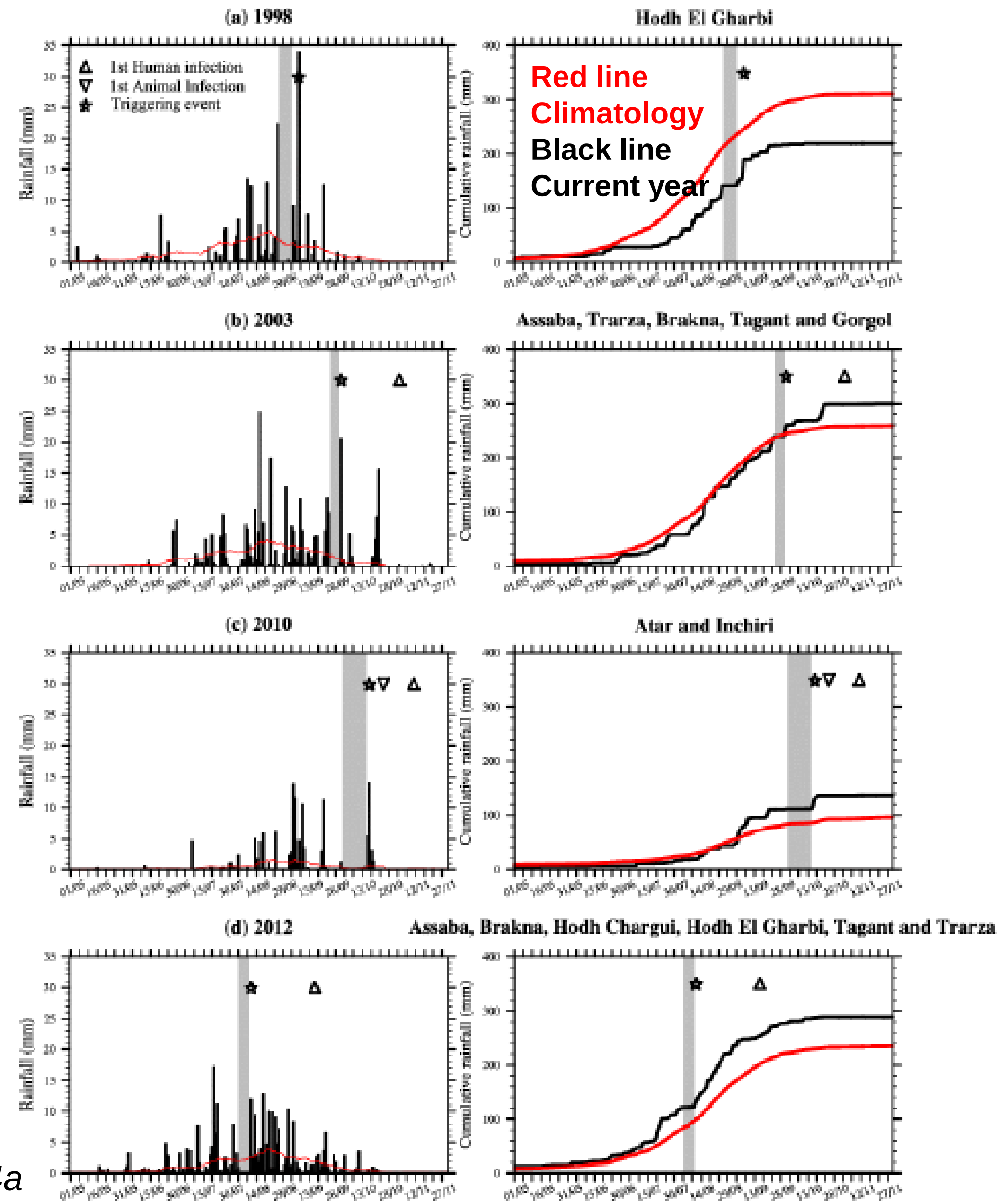
Rift Valley Fever outbreaks in Mauritania





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Caminade et al, 2014a

Asian tiger mosquito: an invasive species

Pathogens

Dengue fever

2 cases in France in 2010 and 2014

Chikungunya fever

Ravenna outbreak in Italy in 2007

Biting nuisances!!!!!

Methods

1) Model its **climatic suitability** using different distribution models.

2) Using an ensemble of Regional Climate Model scenario to design future projections

3) Differences and similarities before addressing recommendations

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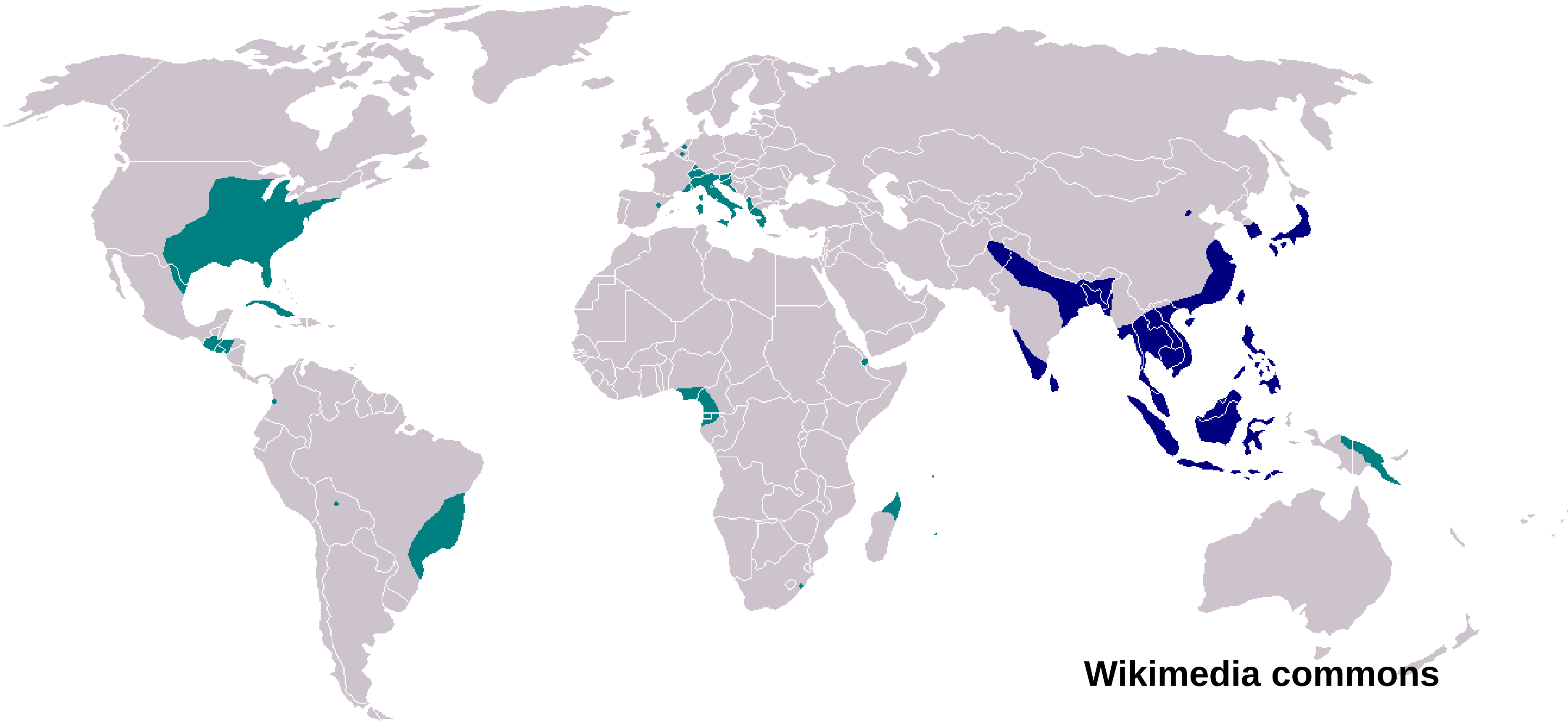
Asian tiger mosquito: distribution



blue: original distribution, cyan: areas where introduced in the last 30 years.

Asian tiger mosquito: Introduction routes

Scholte & Schaffner, 2007

Figure 2. Main Aedes albopictus *inroduction routes: (A) Used tyres. (B),(C) Lucky Bamboo* (Dracaena *spp.).*

Asian tiger mosquito spread in Europe

Scholte & Schaffner, 2007

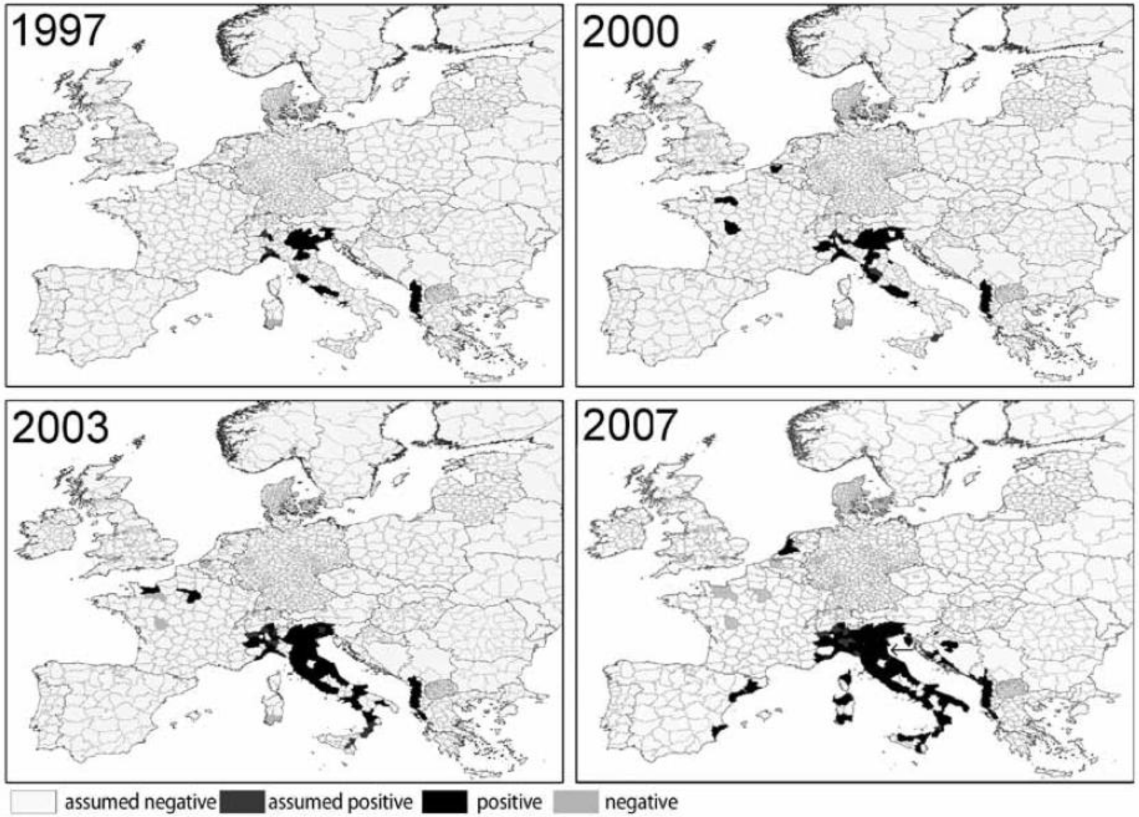
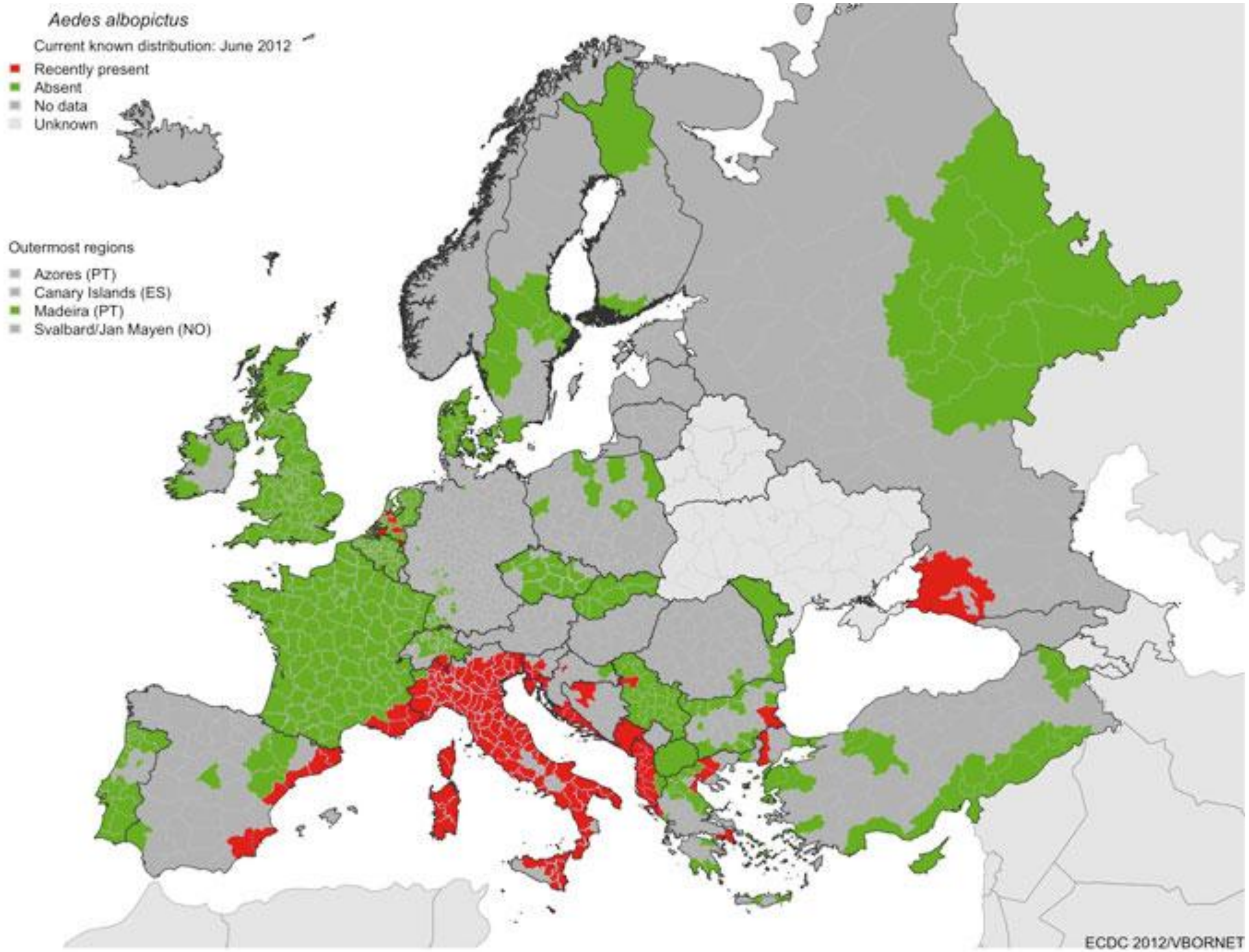


Figure 3. Presence of Aedes albopictus *in Europe per province for the years 1997-2007. Data to complete this figure were kindly made available by Roberto Romi (Italy), Roger Eritja and David Roiz (Spain), Eleonora Flacio (Switzerland), Charles Jeannin (France), Anna Klobučar (Croatia), Zoran Lukac (Bosnia and Herzegovina), Igor Pajovic and Dusan Petrić (Serbia and Montenegro), Bjoern Pluskota (Germany), Anna Samanidou-Voyadjoglou (Greece). The map was made by Patrizia Scarpulla. The 2007 outbreak of Chikungunya virus in Italy is indicated with an arrow in the 2007 box.*

Asian tiger mosquito: distribution in Europe: ECDC/VBORNET framework Jan 2012



Hot spots:

- Italy
- Corsica,
- Sardinia
- Sicily
- Eastern coast of Spain
- Southern France
- Adriatic coast
- Greece

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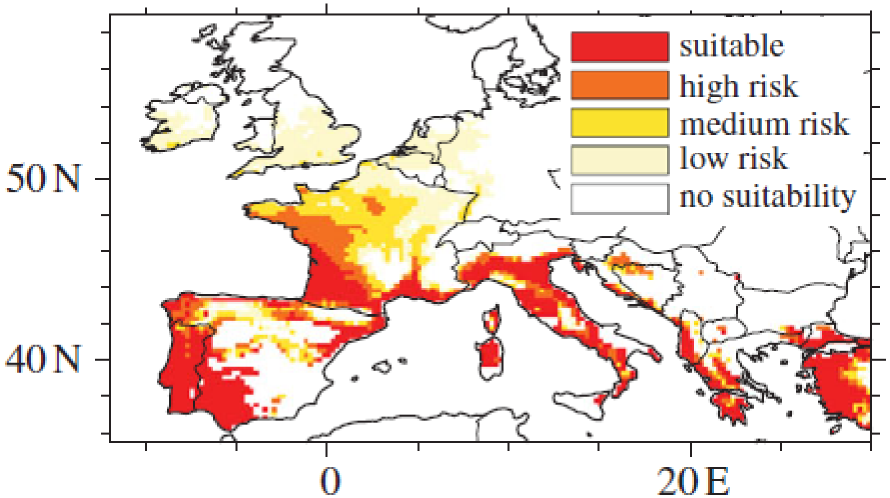
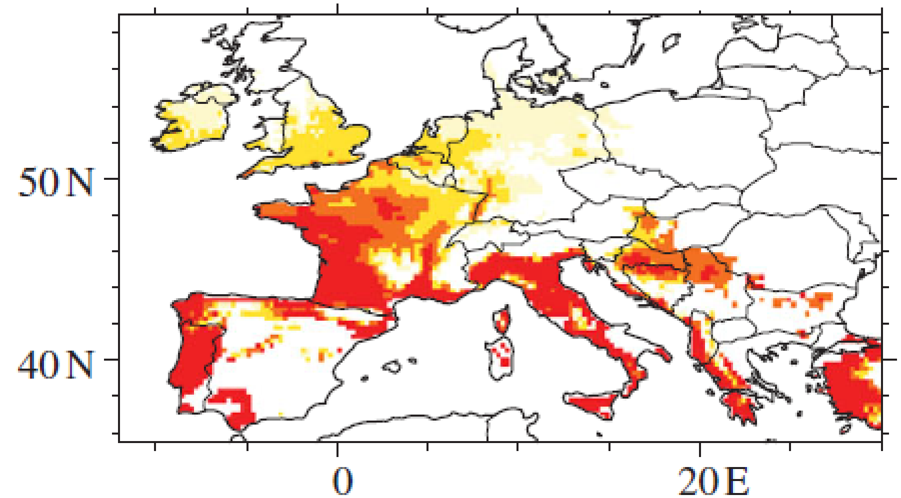
Simulated climate suitability for *A. albopictus*

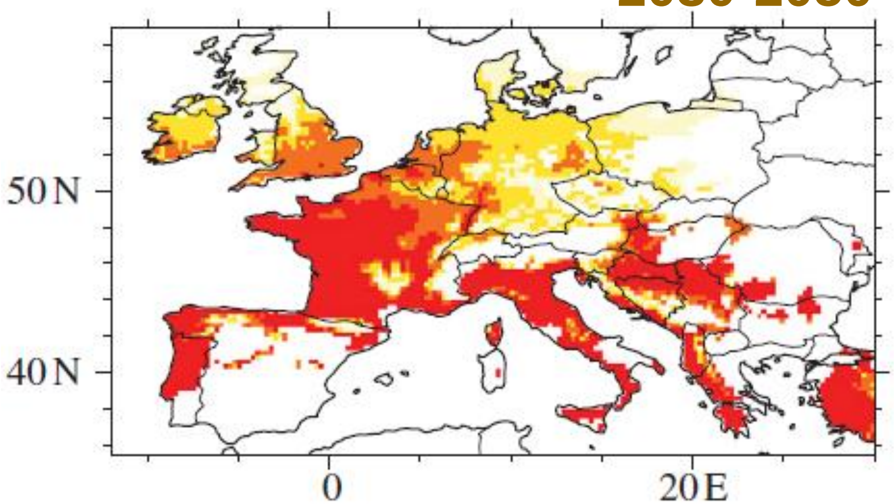
1960-1989



1990-2009



2030-2050



Caminade et al., 2012

Model based on an overwintering criterion (Tjanuary >0C, Rain_annual>500mm) and different thresholds in annual Temperature:

suitable	12C< T_annual
high risk	11C< T_annual < 12C
medium risk:	10C< T_annual < 11C
low risk:	9C< T_annual < 10C
no suitability:	T_annual < 9C

Future risk increase: Benelux, Balkans, western Germany, the southern UK

Future risk decrease: Spain and Mediterranean islands

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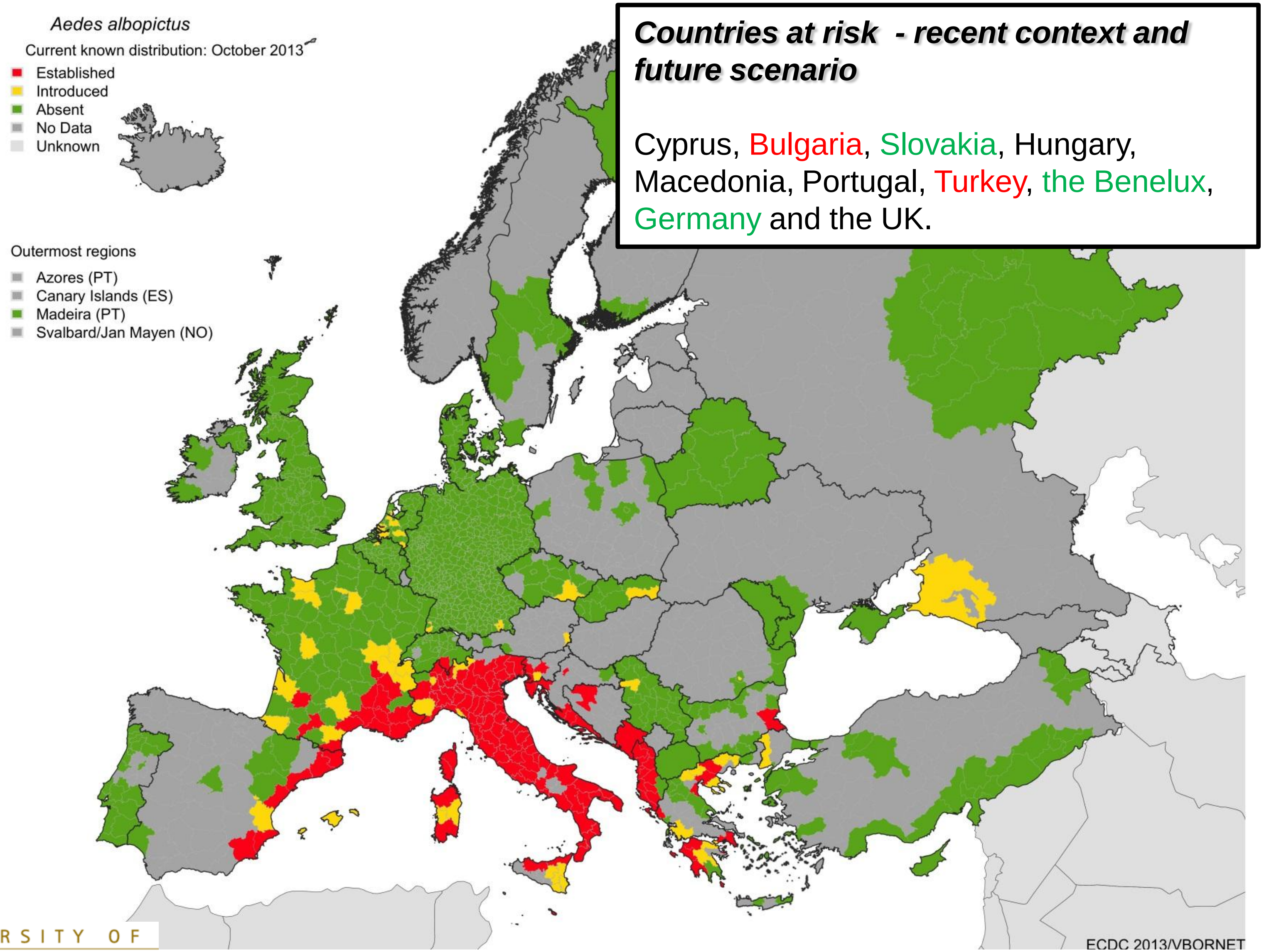
Asian tiger mosquito: distribution in Europe: ECDC/VBORNET October 2013



Countries at risk - recent context and future scenario

Cyprus, Bulgaria, Slovakia, Hungary, Macedonia, Portugal, Turkey, the Benelux, Germany and the UK.

Huge Asian 'tiger' mosquitoes poised to invade UK - and could bring deadly tropical diseases such as dengue fever with them

By ROB WAUGH

PUBLISHED: 03:34, 25 April 2012 | **UPDATED:** 03:34, 25 April 2012

A mosquito that spreads tropical diseases including dengue fever may be poised to invade the UK because of climate change, experts have warned.

The Asian tiger mosquito, Aedes albopictus, has already been reported in France and Belgium and could be migrating north as winters become warmer and wetter.

Scientists urged 'wide surveillance' for the biting insect across countries of central and northern Europe, including the UK.

The Asian tiger mosquito, Aedes albopictus, has already been reported in France and Belgium and could be migrating north as winters become warmer and wetter

07|13|13 ISSUE

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The cabbage's clock: Plants continue their biological routines even after being picked

Amputated 'finger' tips grow back: Both toenails and toe tips grew back in mice, thanks to special

Home / June 29, 2013; Vol.183 #13

In the Eye of the Tiger

Global spread of Asian tiger mosquito could fuel outbreaks of tropical disease in temperate regions

ShareThis Tweet Share +1

By Carrie Arnold

Web edition: June 13, 2013

Print edition: June 29, 2013; Vol.183 #13 (p. 26)

A+ A- Text Size

domestic animals.

James Gathany/CDC

There is no shortage of mosquitoes in North America, and adding one more variety might seem like just a minor uptick in summertime's itchy-scratchy. But the Asian tiger mosquito, *Aedes albopictus,* comes with some particularly irritating characteristics. It's an aggressive hit-and-run biter that frequently lives in close

Google earth video on youtube:

http://www.youtube.com/watch?v=WFqmNgtXOrM

People in the southeastern United States are already well acquainted with the Asian tiger, named for its black-and-white stripes. But these mosquitoes are creating quite a buzz as they drift northward into more temperate climates along the East Coast, where their eggs can survive even cold winters.

The buzz would be just so much hand-wringing if it didn't include an alarming public health component: The Asian tiger turns out to be a competent vector for a raft of diseases, some lethal. It can carry dengue fever, yellow fever, chikungunya virus, West Nile fever and two forms of encephalitis named for St. Louis, Mo., and La Crosse, Wis. Among these diseases, only yellow fever is preventable by vaccine. Ominously, dengue has already gotten a toehold in southern parts of the United States.

Kicking the competition

The Asian tiger mosquito has joined a rogues' gallery of invasive species — including zebra mussels, red imported fire ants and Africanized bees — now established in North America. In Florida and other subtropical parts of the Deep South, it has shown clear signs of displacing a predecessor-in-crime, the *Aedes aegypti* mosquito, which is best known for spreading yellow fever before that scourge was quelled by a vaccine. While it's unclear whether the Asian tiger has muscled out resident mosquitoes farther north, one

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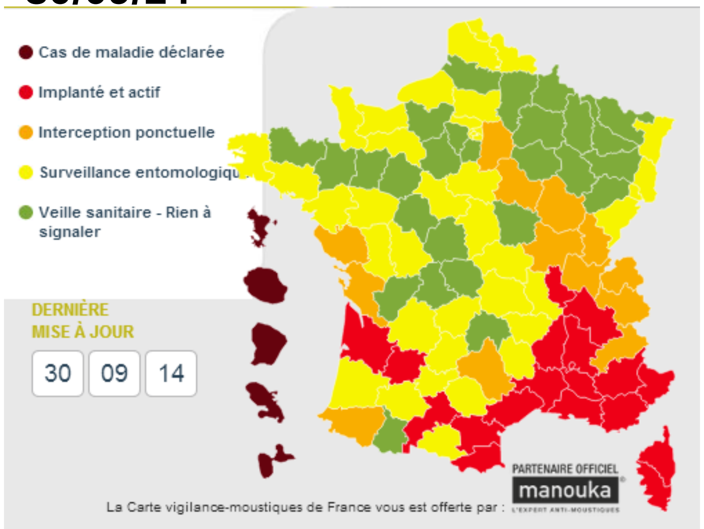
BLOGS & COLUMNS

Becoming Human

Human ancestors scrambled to their feet, a new

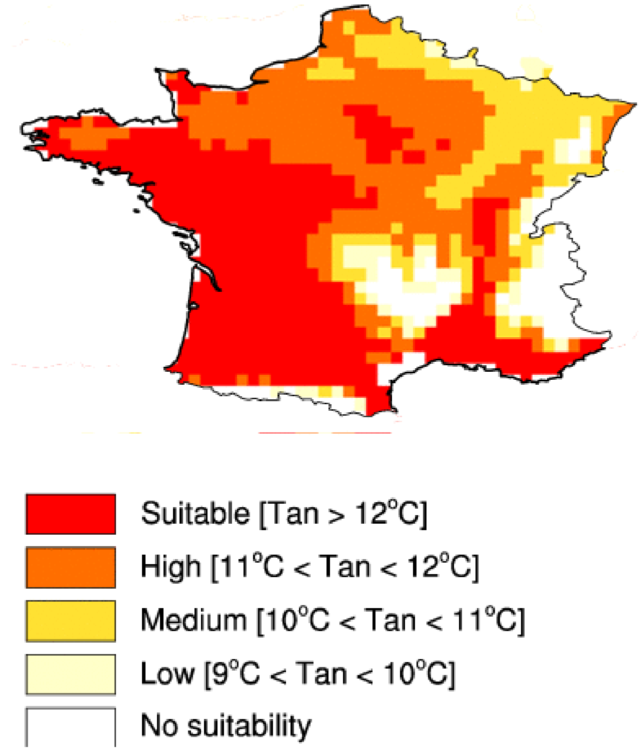
An update for France *1999-2013*

Observation 30/09/14



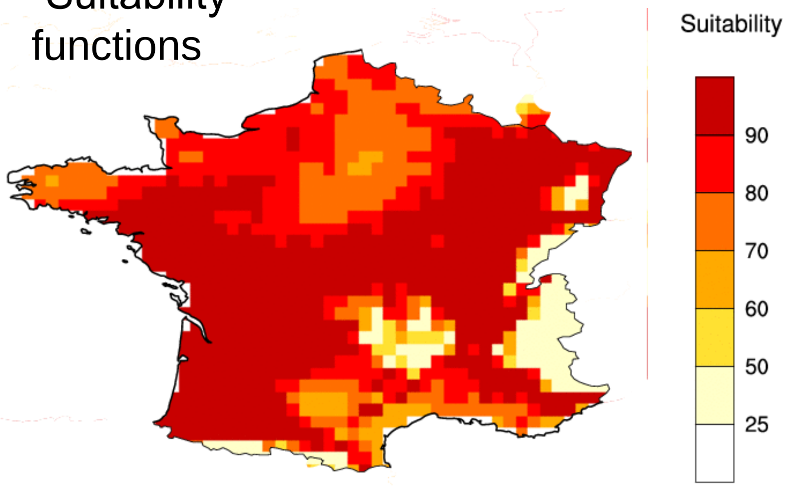
Model 1

Overwintering + Annual Temperature and rainfall thresholds



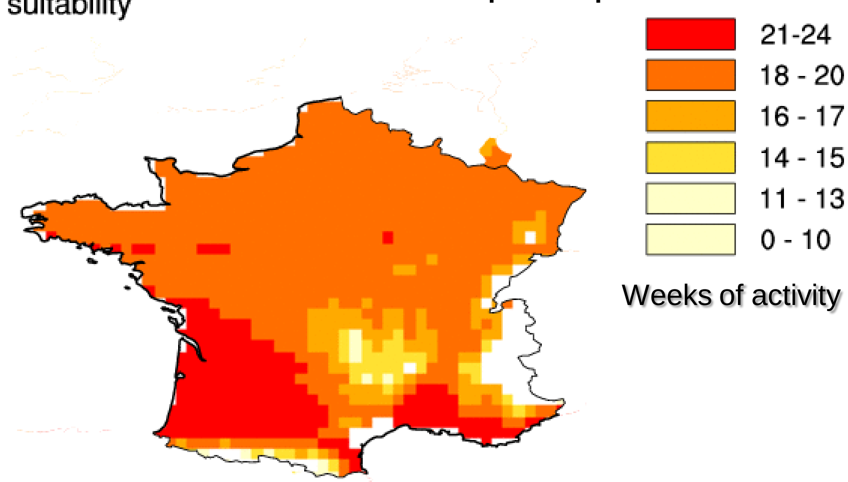
Model 2

"Suitability" functions



Model 3

Overwintering, temperature and photoperiod



Malaria Background

- Caused by *Plasmodium spp* parasite which is transmitted by bites of the *Anopheles spp* mosquito
- WHO Global elimination program in mid-20th C was successful in Europe and USA
- Now mainly sub-Saharan Africa (*P. Falciparum*) (91%) and Asia (*P. Falciparum and P. Vivax*)
- Mainly affects children, pregnant women and elders
- Estimated 660,000 deaths worldwide in 2010
- Fallen 33% in sub-Saharan Africa since 2000 -> Roll Back Malaria Programme, Bill & Melinda Gates fundation, World Bank Malaria Booster programme...
- ISI-MIP – QWeCI - Healthy Futures EU projects: Using an ensemble of malaria models to simulate the risk in malaria transmission for the recent context and the future

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Malaria Distribution 1948

Source: WHO

ISI-MIP framework (methodology)

ISI-MIP Inter-Sectoral Impact Model Inter-comparison.

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

Five malaria models investigated: MARA, LMM_ro, Vectri, Umea & MIASMA for P. falciparum

- Output Variables:
  - Length of the malaria transmission season e.g. LTS (in months)
  - Malaria climatic suitability (binary 0-1). Defined if LTS >=3 months
  - Additional person/month at risk for the future.

Bias corrected climate scenarios were available for all RCPs [2.6, 4.5, 6, 8] emission scenarios and the historical simulations for **5 GCMs.** Population scenario **SSP2 (UN)**

- GCM1 - HadGem2-ES
- GCM2 - IPSL-CM5A-LR
- GCM3 - MIROC-ESM-CHEM
- GCM4 - GFDL-ESM2M
- GCM5 - NorESM1-M

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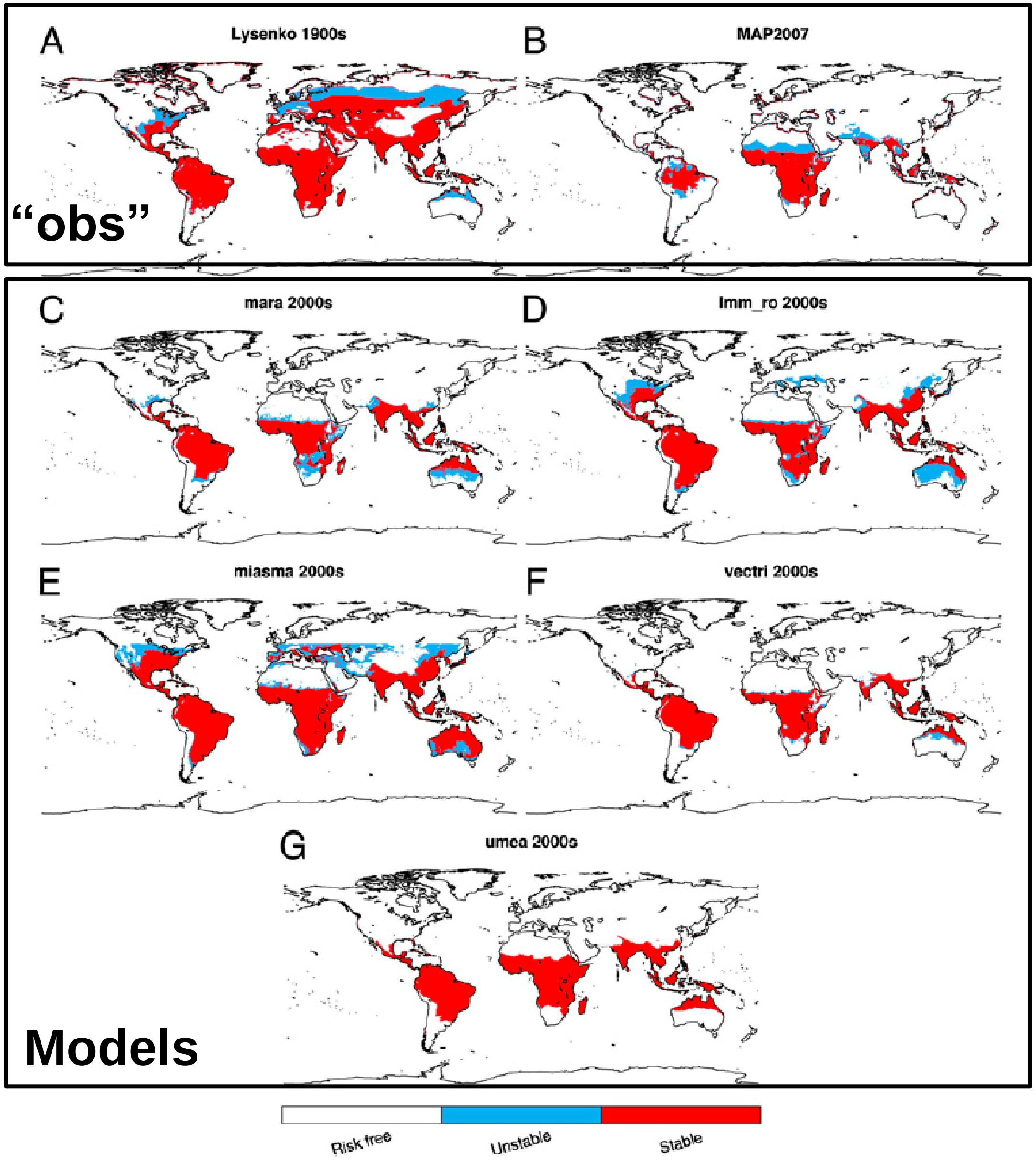
Malaria Background 1900s vs 2000s

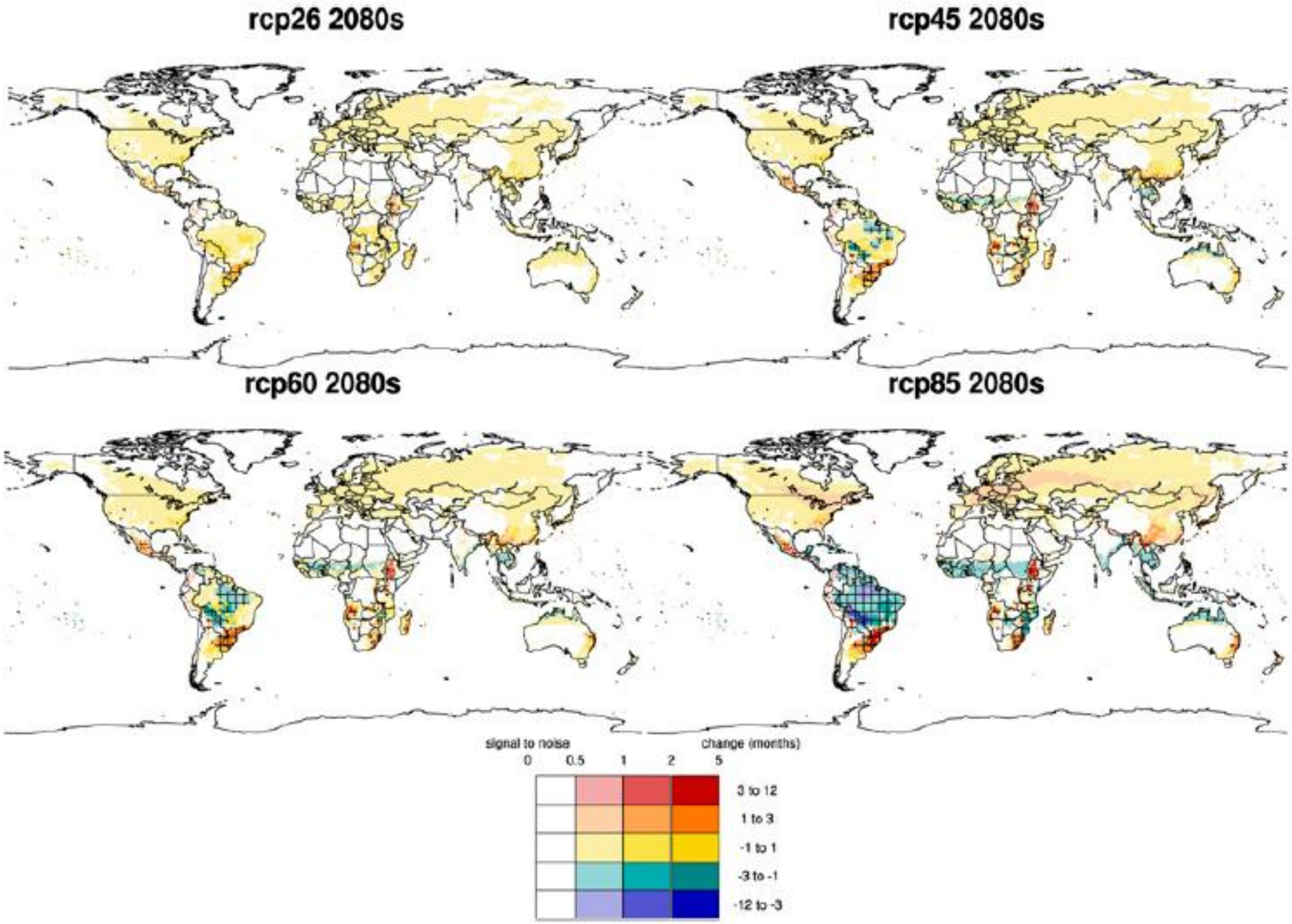


Malaria endemicity decreased worlwide Mainly due to intervention (bed nets, early diagnostic tests, vector control…)

Fig. 1. Observed (*A* and *B*) and simulated malaria distribution (three categories: risk-free in white, unstable/epidemic in blue, and stable/endemic in red) for five malaria models (*C*, *D*, *E*, *F* and *G*). For the observation (*A* and *B*) all endemic subcategories (hypoendemic, mesoendemic, hyperendemic, and holoendemic) have been included in the stable category. The 1900s data (*A*) are based on ref. 38 (considers all plasmodium infections), and the 2000s data (*B*) are based on ref. 14 (considers only *P. falciparum* infections). For the simulations, unstable malaria is defined for a length of the transmission season (LTS) ranging between 1 and 3 mo, and suitable is defined for LTS above 3 mo (based on TRMMERAI control runs for the period 1999–2010; *SI Appendix*, Fig. S11 shows the CRUTS3.1 control runs). The TRMMERAI runs are constrained to span 50°N–50°S owing to the TRMM satellite data availability. For the UMEA malaria model only estimates of stable malaria were available.

Caminade et al., 2014

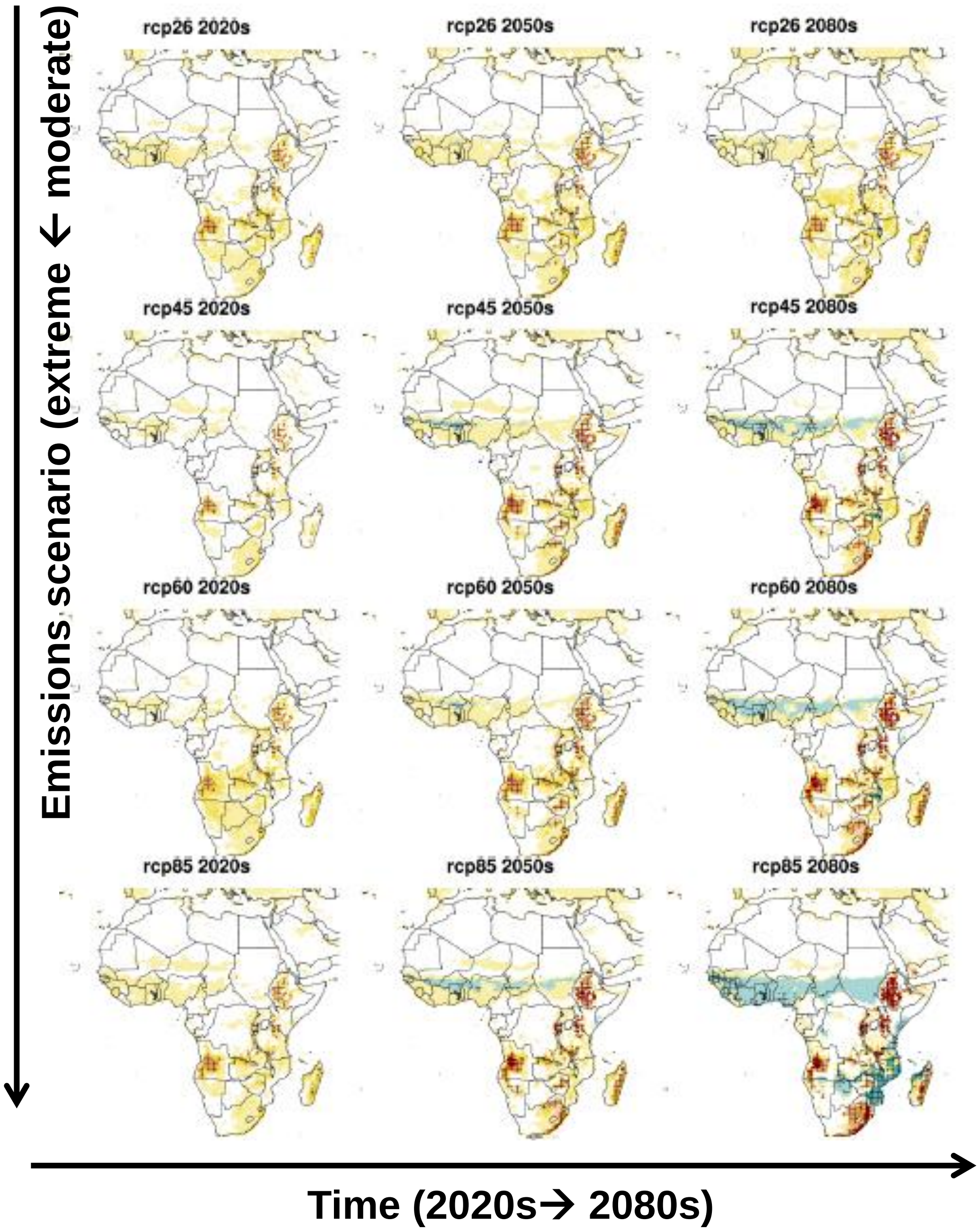
Impact of climate change on malaria distribution



Climatic suitability simulated to increase for all malaria models over the Tropical highland regions.

Caminade et al., 2014

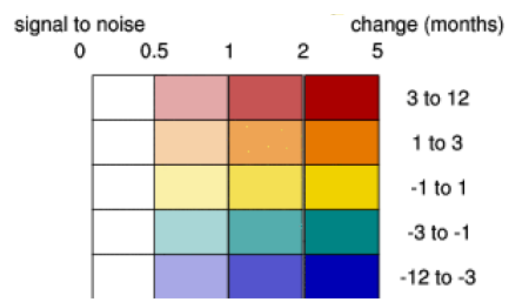
Malaria 21st century scenario



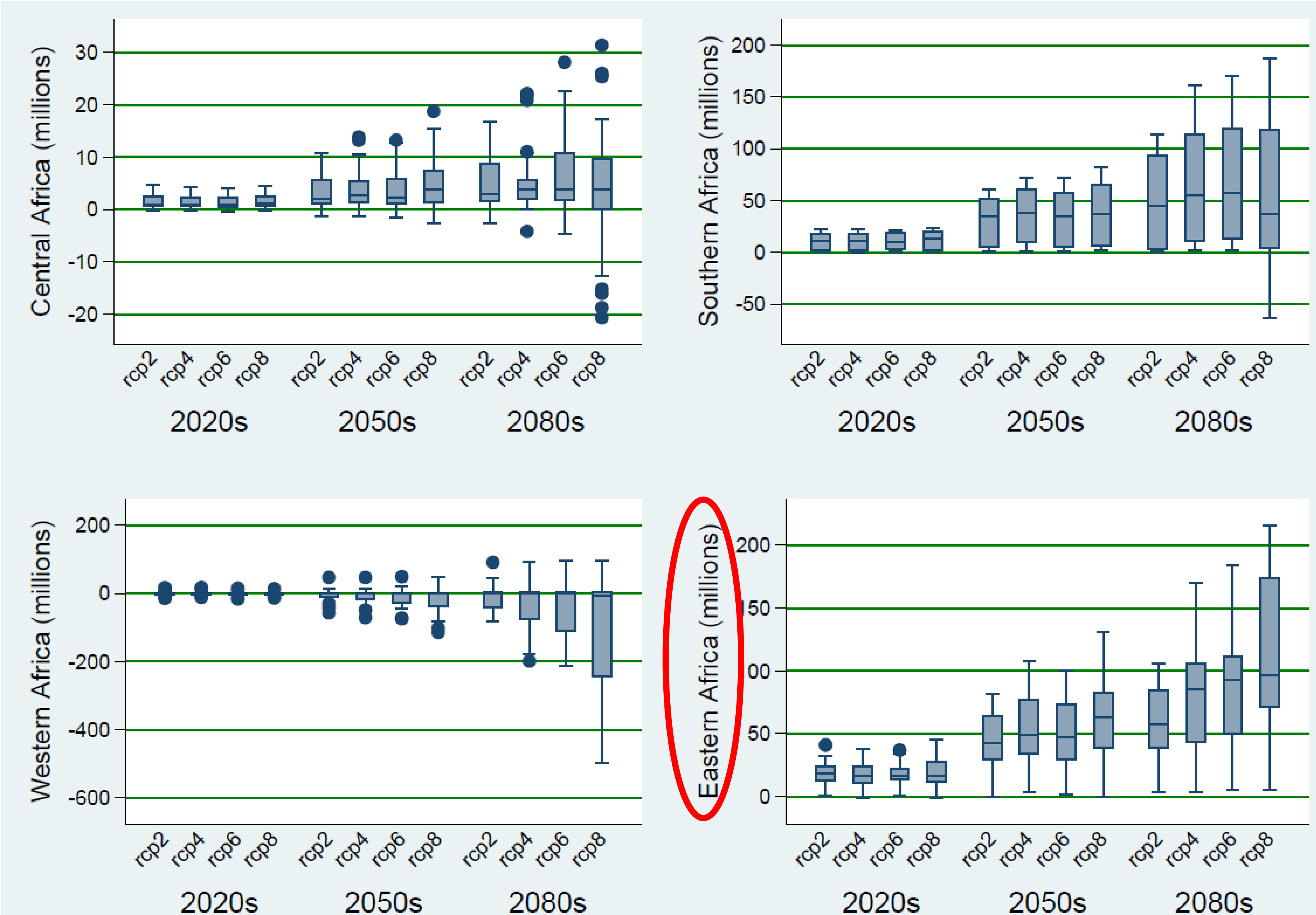
The effect of climate scenarios on future malaria distribution: changes in length of the malaria season.

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

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



Future population at risk



New certainty that malaria will 'head for the hills'

published on February 6 2014
this article has no comments

The researchers found that the changing climate will allow malaria to move into higher altitudes during warmer seasons and become permanently resident in larger areas

Previously unaffected areas of Africa, Asia, and South America could be at risk from malaria as the infection moves into upland areas by the end of the century, a University of Liverpool study has shown.

For the first time, scientists have compared the latest predictions for global warming with a range of statistical models, commonly used to predict the spread of malaria. The models showed that in 2080, the climate at higher altitudes will become increasingly suitable for malaria, affecting millions of people: mainly in Africa, and to a lesser extent in Asia and South America.

Additional 100 million people exposed

In eastern Africa this could result in an additional 100 million people being exposed to malaria by the end of the 2080s.

Dr Cyril Caminade, a population and epidemiology researcher who led the project, said: "There has been a lot of uncertainty about how malaria will spread as a result of climate change, but by using all of the models available to us, we've been able to pin down a few highly likely

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Viewpoint: Floods – learning from the past

A few weeks later in Science (based on field observations)

Altitudinal Changes in Malaria Incidence in Highlands of Ethiopia and Colombia

A. S. Siraj,[1]* M. Santos-Vega,[2]* M. J. Bouma,[3] D. Yadeta,[4] D. Ruiz Carrascal,[5,6] M. Pascual[2,7]†

The impact of global warming on insect-borne diseases and on highland malaria in particular remains controversial. Temperature is known to influence transmission intensity through its effects on the population growth of the mosquito vector and on pathogen development within the vector. Spatiotemporal data at a regional scale in highlands of Colombia and Ethiopia supplied an opportunity to examine how the spatial distribution of the disease changes with the interannual variability of temperature. We provide evidence for an increase in the altitude of malaria distribution in warmer years, which implies that climate change will, without mitigation, result in an increase of the malaria burden in the densely populated highlands of Africa and South America.

More scientific evidences that climate becomes increasingly suitable for malaria in the Tropical highlands but other parameters will be critical:

Population movements and urbanisation

Technological development (vector control, vaccine?)

Land surface changes (agriculture: fisheries, rice paddies…)

Adaptation and evolution (mosquitoes resistance to insecticide, parasite resistance to drugs…)

Socio-economic development (changes in wealth and vulnerability)

Indirect effects of climate change

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Journal of the American Mosquito Control Association, 14(2):121–130, 1998

EVOLUTION OF MALARIA IN AFRICA FOR THE PAST 40 YEARS: IMPACT OF CLIMATIC AND HUMAN FACTORS

JEAN MOUCHET,[1] SYLVIE MANGUIN,[2] JACQUES SIRCOULON,[1] STÉPHANE LAVENTURE,[3] OUSMANE FAYE,[4] AMBROSE W. ONAPA,[5] PIERRE CARNEVALE,[6] JEAN JULVEZ[7] AND DIDIER FONTENILLE[8]

ABSTRACT. Different malarial situations in Africa within the past 40 years are discussed in order to evaluate the impact of climatic and human factors on the disease. North of the equator, more droughts and lower rainfall have been recorded since 1972; and in eastern and southern Africa, there have been alternating dry and wet periods in relation to El Niño. Since 1955, the increase in human population from 125 to 450 million has resulted in both expansion of land cultivation and urbanization. In stable malaria areas of West and Central Africa and on the Madagascar coasts, the endemic situation has not changed since 1955. However, in unstable malaria areas such as the highlands and Sahel significant changes have occurred. In Madagascar, cessation of malaria control programs resulted in the deadly epidemic of 1987–88. The same situation was observed in Swaziland in 1984–85. In Uganda, malaria incidence has increased more than 30 times in the highlands (1,500–1,800 m), but its altitudinal limit has not overcome that of the beginning of the century. Cultivation of valley bottoms and extension of settlements are in large part responsible for this increase, along with abnormally heavy rainfall that favored the severe epidemic of 1994. A similar increase in malaria was observed in neighboring highlands of Rwanda and Burundi, and epidemics have been recorded in Ethiopia since 1958. In contrast, in the Sahel (Niayes region, Senegal), stricken by droughts since 1972, endemic malaria decreased drastically after the disappearance of the main vector, *Anopheles funestus,* due to the destruction of its larval sites by cultivation. Even during the very wet year of 1995, *An. funestus* did not reinvade the region and malaria did not increase. The same situation was observed in the Sahelian zone of Niger. Therefore, the temperature increase of 0.5°C during the last 2 decades cannot be incriminated as a major cause for these malaria changes, which are mainly due to the combination of climatic, human, and operational factors.

KEY WORDS Malaria, Africa, *Anopheles gambiae, Anopheles funestus,* climatic factors, human factors

Conclusions and Perspectives

- More evidences that climate change contributed to the rise of infectious diseases **but**: other factors to consider: increased travel, land use, vulnerability, drug resistance…
- Current disease models at their infancy stages (mosquitoes experience weather instead of climate)
- Multi data source simulations useful and needed (using ensembles of disease models, climate models, population and climate change scenarios)
- Stop the race for model skill: look at where things might occur instead of where things really occurred to anticipate the risk
- Multi-disciplinary projects (entomologists, epidemiologists, human and animal health specialists, climatologists-meteorologists, human scientists, interface scientists) e.g. One Health approach
- CMIP5 for IPCC should be a standard for multi-disease model risk assessment – international and national initiatives (ESCRIME for impacts of climate change or isi-mip initiative)