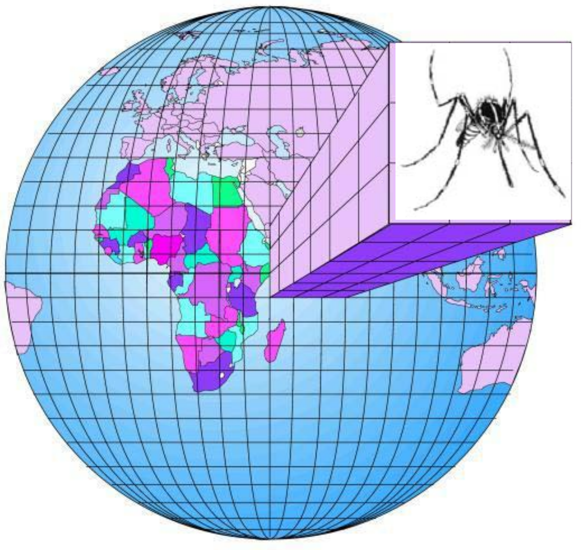
Modéliser l'impact du réchauffement climatique sur les maladies infectieuses vectorielles



Dr C. Caminade

Institute of Infection and Global Health (EPH) – School of Environmental Sciences

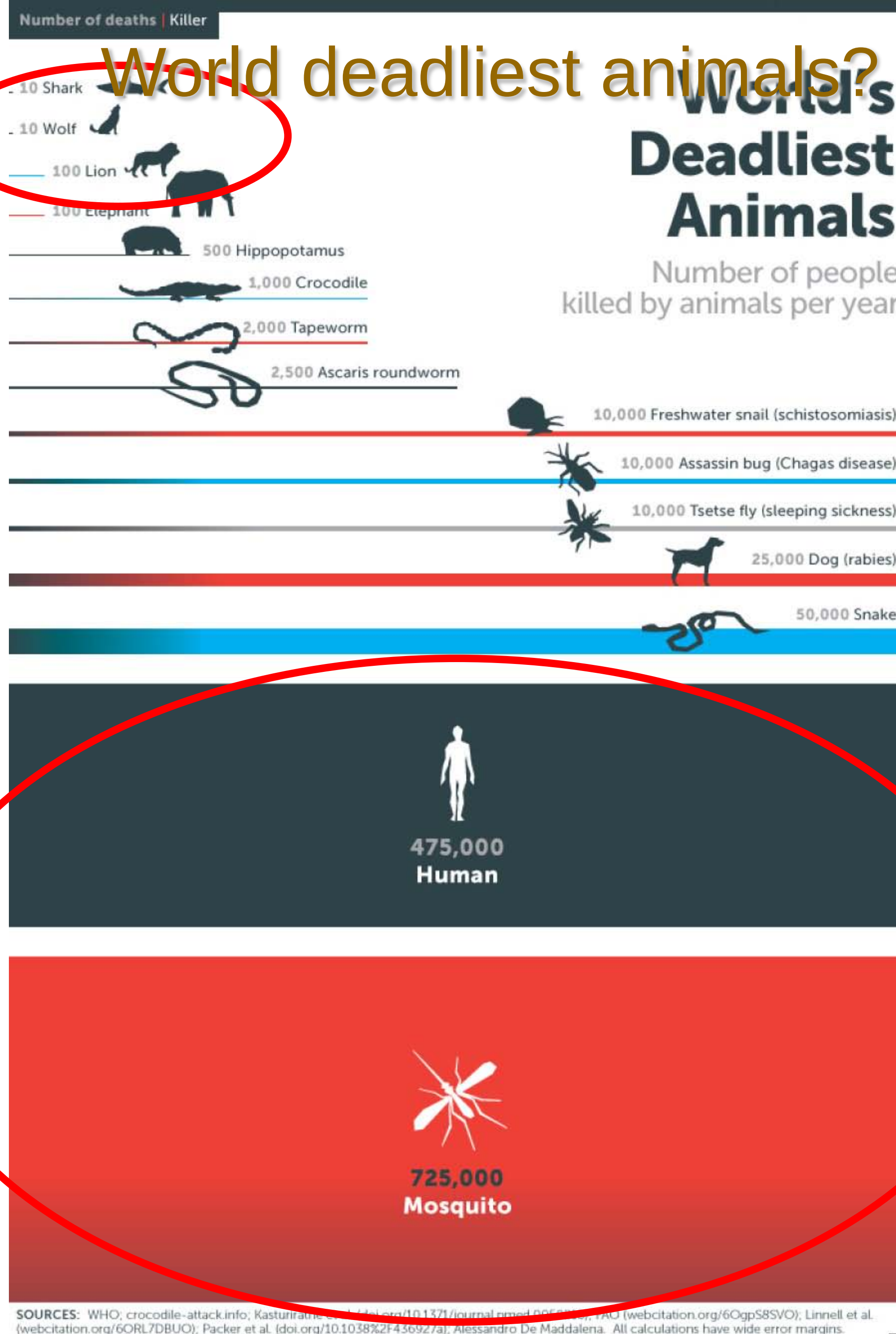
email: Cyril.Caminade@liverpool.ac.uk

***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, Diana Williams, 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, Adrian Tompkins (ICTP) and many more…*

World deadliest animals?

Irrational fear

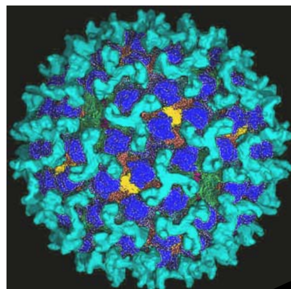
Facts



Vector Borne diseases

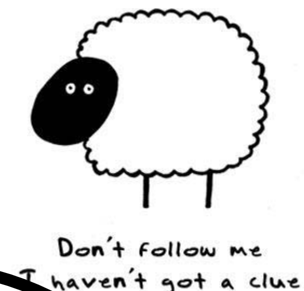
Diseases transmitted by blood sucking arthropods, worms…

Pathogen



- Survival
- Replication rate

Host



- Growth rate
- Survival
- Distribution
- Life habits

Vector

- Breeding sites
- Survival
- Development rate
- Activity
- Length of gonotrophic cycle
- Vector competence
- Biting rate

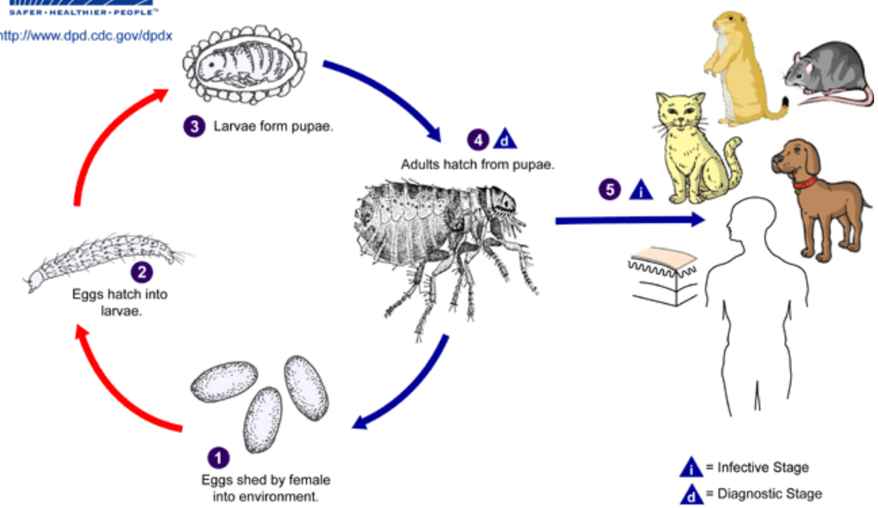
Climate variability
Rainfall
Temperature
Humidity
Winds...

Future climate change?

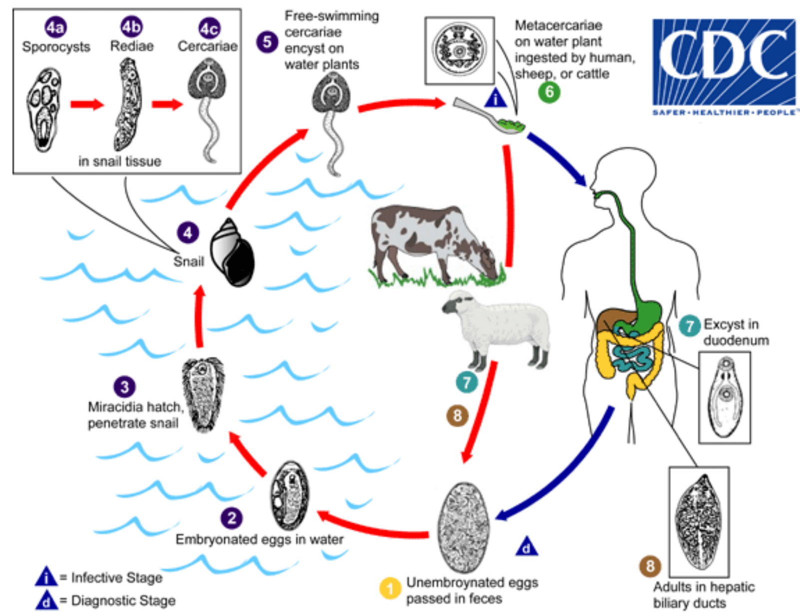
Vector Borne diseases: a few examples

Plague

http://www.dpd.cdc.gov/dpdx

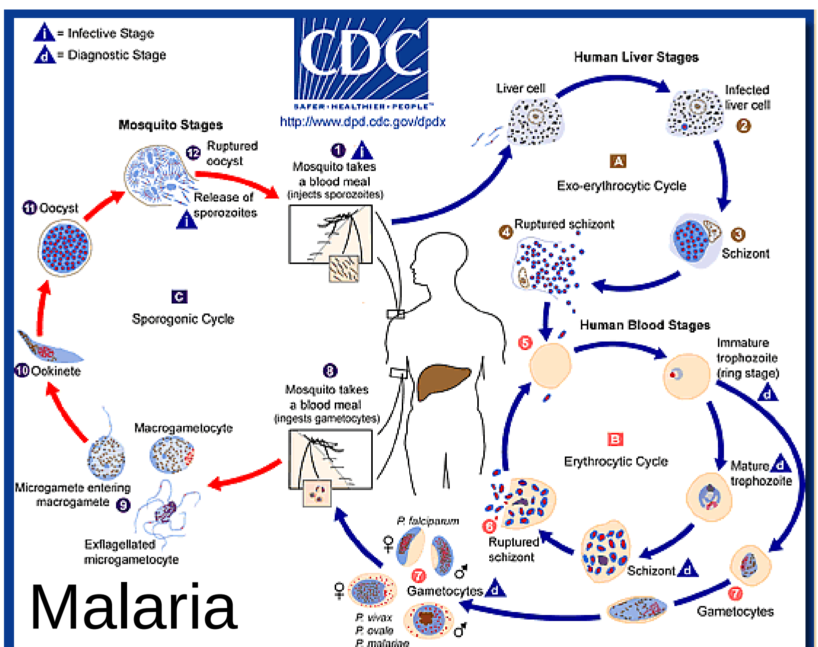


Fasciolosis



Malaria

http://www.dpd.cdc.gov/dpdx



VBDs are complex systems including different forms of pathogens, different vectors and various intermediate / final hosts
-> Surveillance and need for modelling (early warning systems, scenarios)

source: CDC

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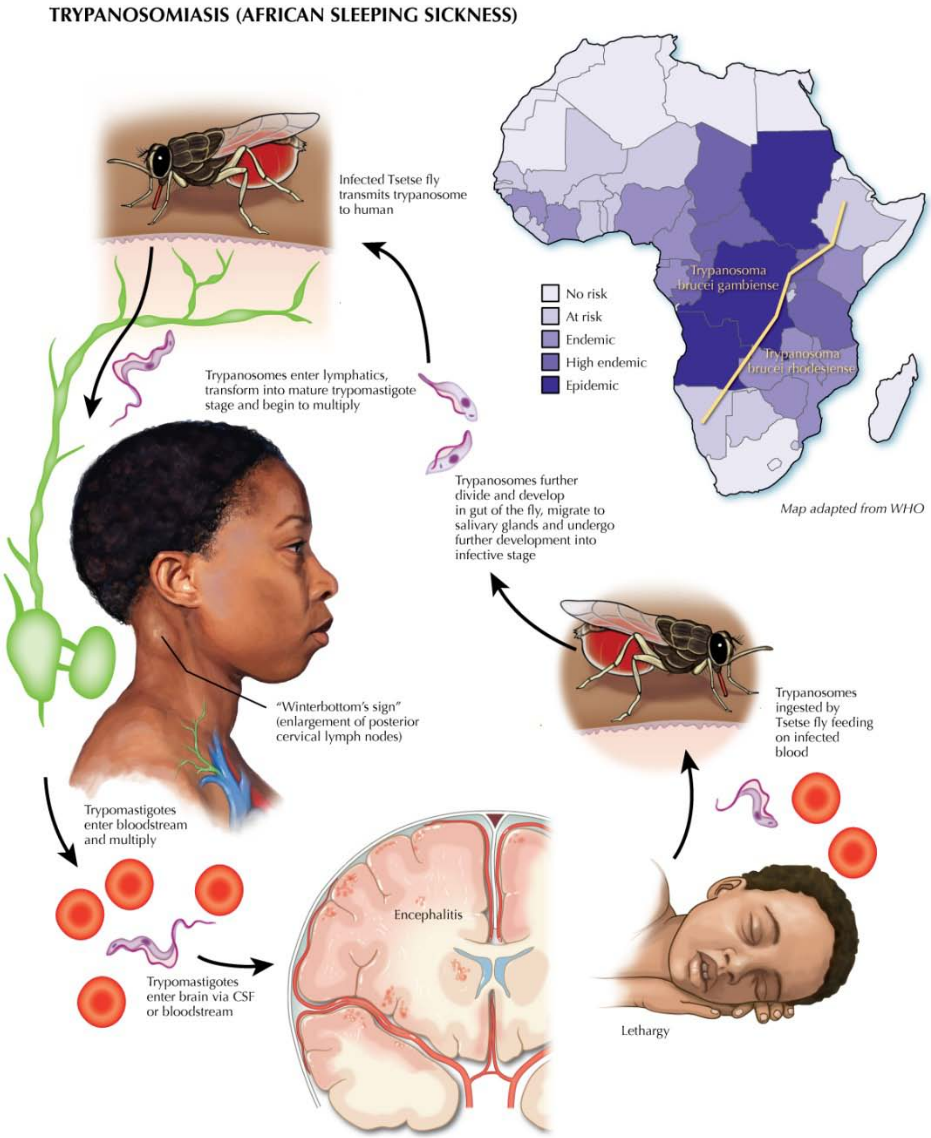
Vector Borne diseases: Impacts

Black death epidemic
in Europe in 1340s-1350s wiped out about a third of the European population



Before I start (disclaimer)

Observations & surveillance:
Partial representation of real disease burden (due to the quality and quantity of contemporary disease data), especially in the developing world, but this is getting better.

Examples: under-reporting of dengue cases at global scale, under-reporting of malaria cases in India, spatio-temporal biases (hospital locations, late-outbreak intervention, differences in health services and health data quality across countries…) – Analogy with Met station data available for central Africa

Models:
George E.P. Box (statistician):
“Essentially, **all models are wrong**, **but some are useful**“

Modelling VBDs: statistical & dynamical approaches

Statistical-dynamical modelling

Statistical modelling

Empirical relationship between disease and sets of covariates:
Disease(X,t)=F(predictors(X,t))
F can be based on different methods:

- *Bayesian modelling*
- *Maxent*
- *Logistic / Poisson regression*
- *BioMod…*

Pros: powerful in terms of model skill (fit) at small spatial and temporal scales, multiple predictors included (climatic factors, socio-economics, urbanisation…).
Cons: relationships between outcome and predictors are assumed to be stationary for the recent context and the future, difficult to extract mechanisms and extrapolate, link between climate model scenarios and disease outcome generally poorly represented (using static seasonal averages, only one climate model...).

Dynamical modelling

Explicit mechanical modelling of disease dynamics, generally derived from lab/field data (vector –pathogen dynamics, host-vector interactions, SEIR approach).
It can be based on different methods:

- *SEIR Model (differential equations)*
- *Ro (spread of an outbreak)*
- *Dynamical climate suitability estimates…*

Pros: Ideally the best approach IF all mechanisms were known (far to be the case) and all drivers were perfect. Easy to integrate in the past and the future. Takes into account changes in climate variability.
Cons: Too climate-centric. Difficulty to obtain long time series for socio-economic data, demographics as inputs to drive the dynamical model (but this is improving).
Large model differences can be obtained by changing model parameterization.

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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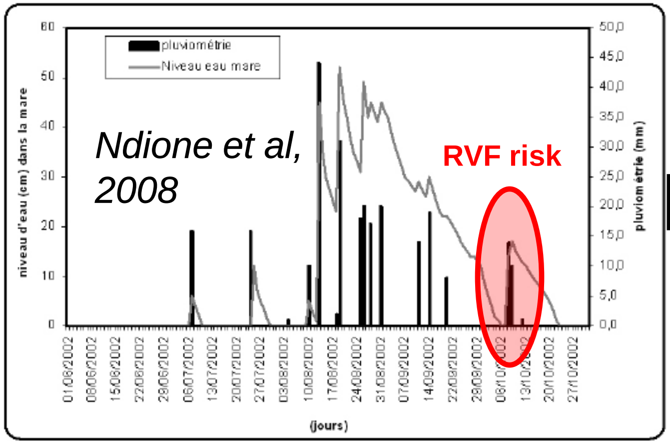
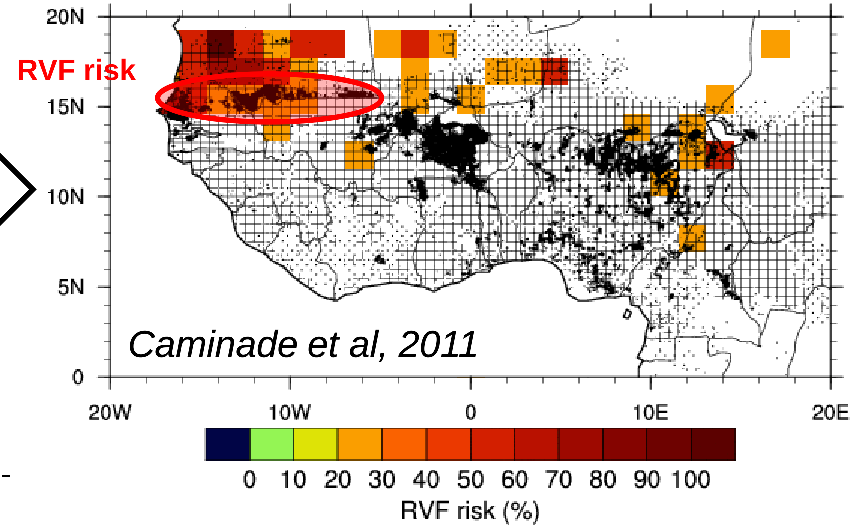
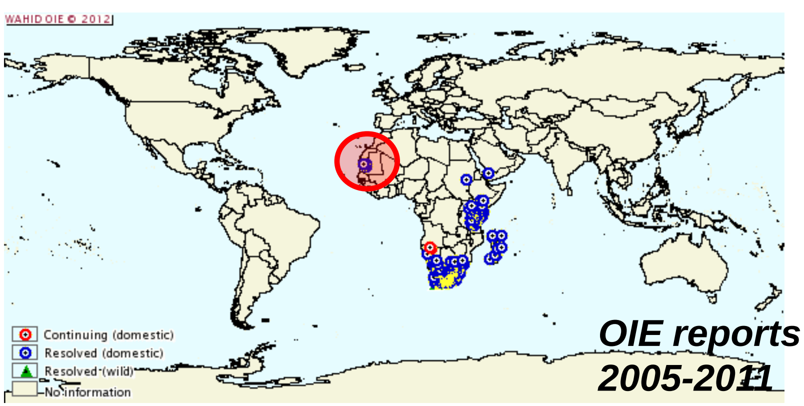
Rift Valley Fever & climate





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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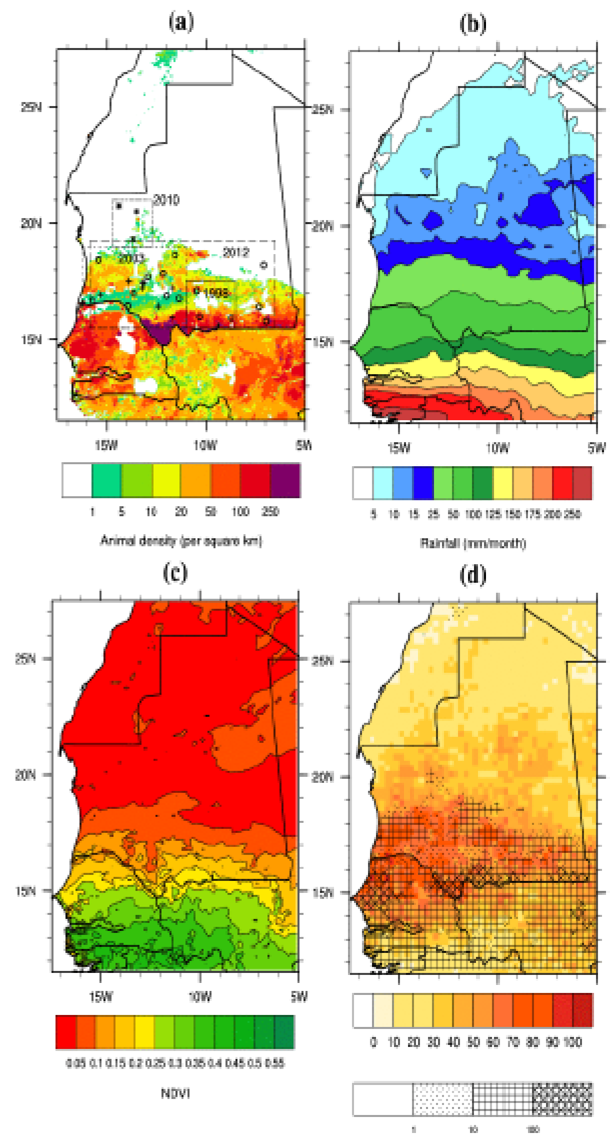
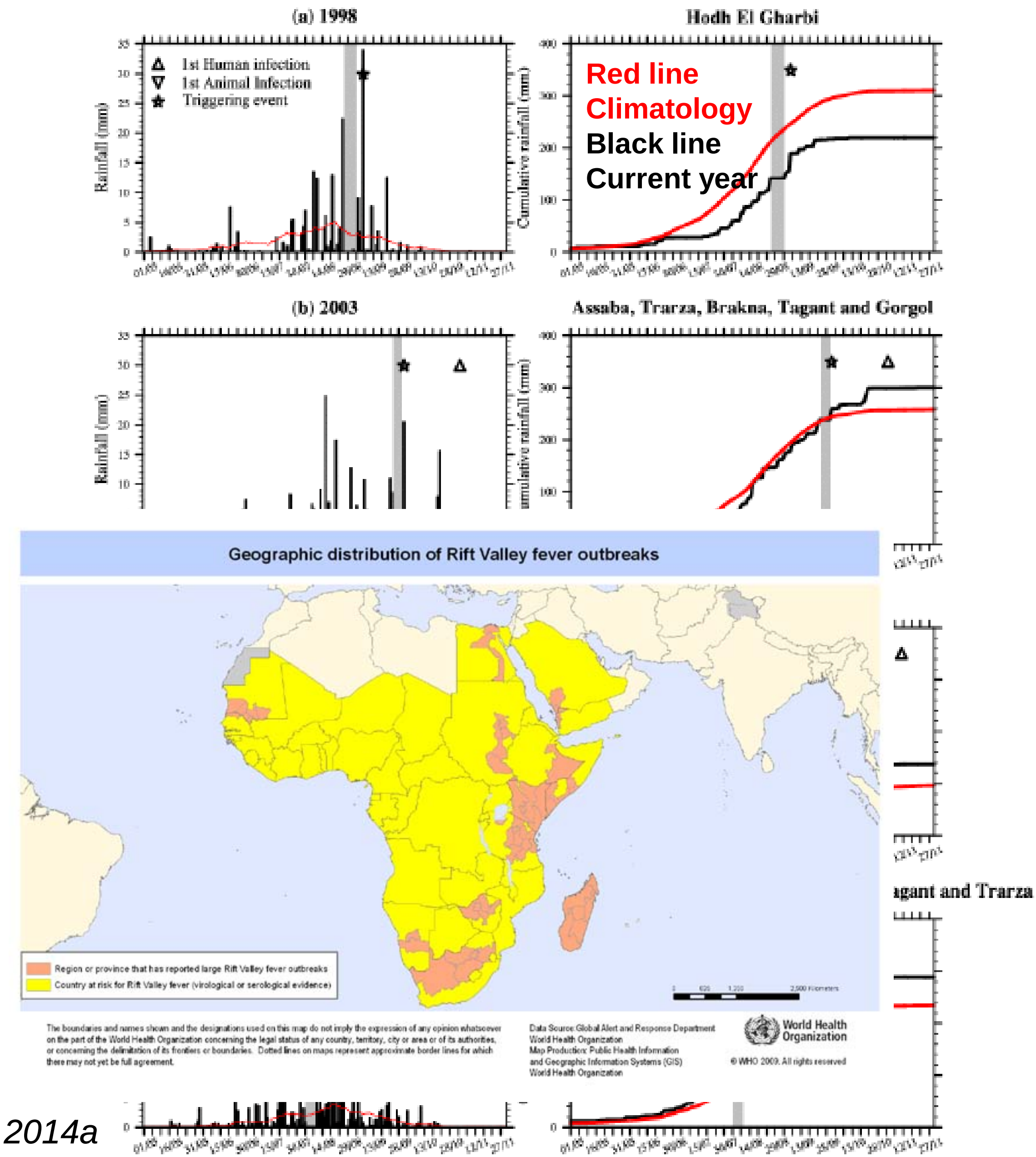
Rift Valley Fever outbreaks in Mauritania





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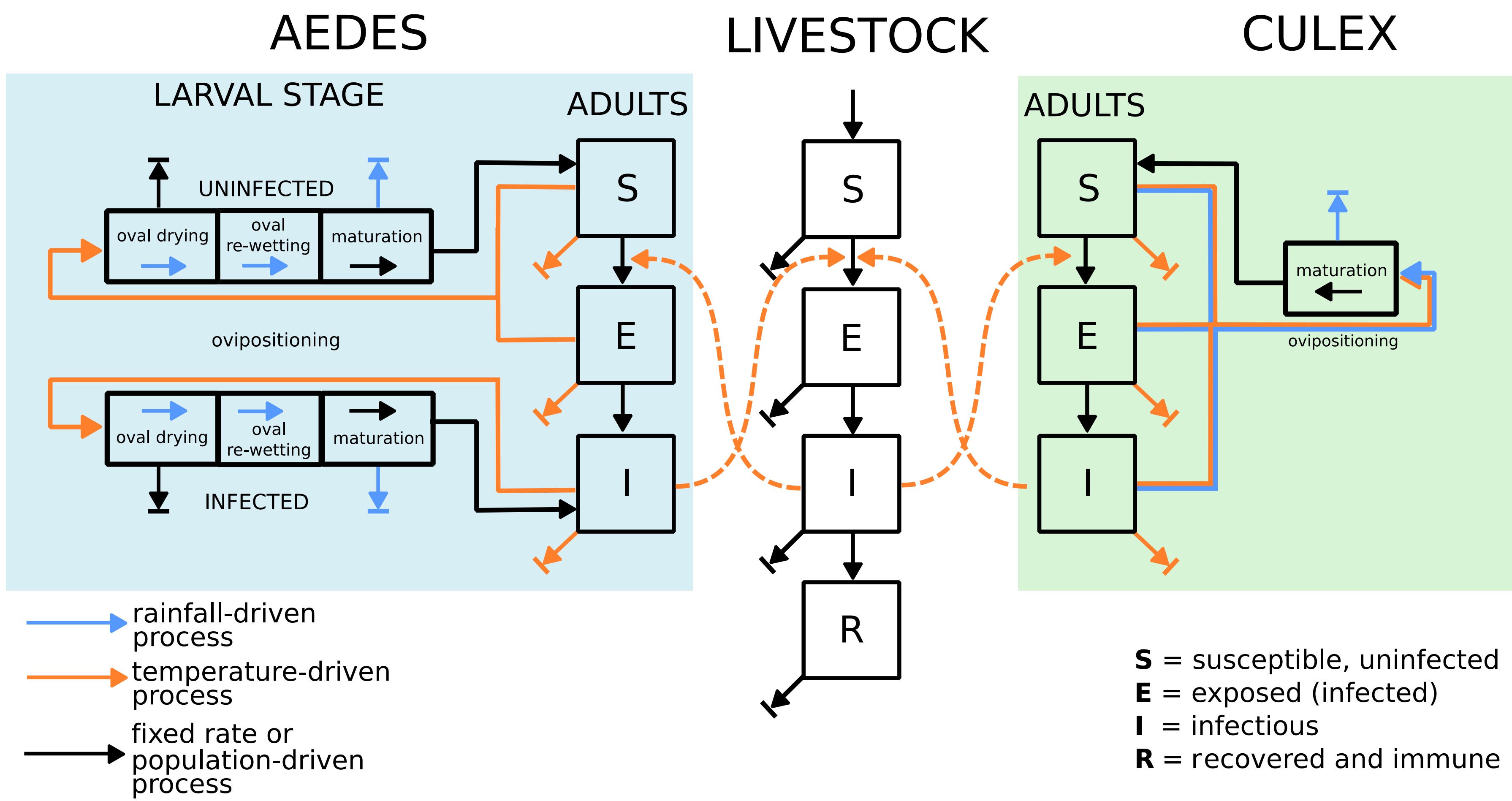
Caminade et al, 2014a

Next step: building a dynamical RVF model…



Slide: Anne Jones

Leedale et al., 2015-16 (in review)

Asian tiger mosquito: an invasive species

Pathogens

Dengue fever

A few autochtoneous cases in France in 2010, 2013, 2015...

Chikungunya fever

Ravenna outbreak in Italy in 2007

Biting nuisances / allergic reaction!

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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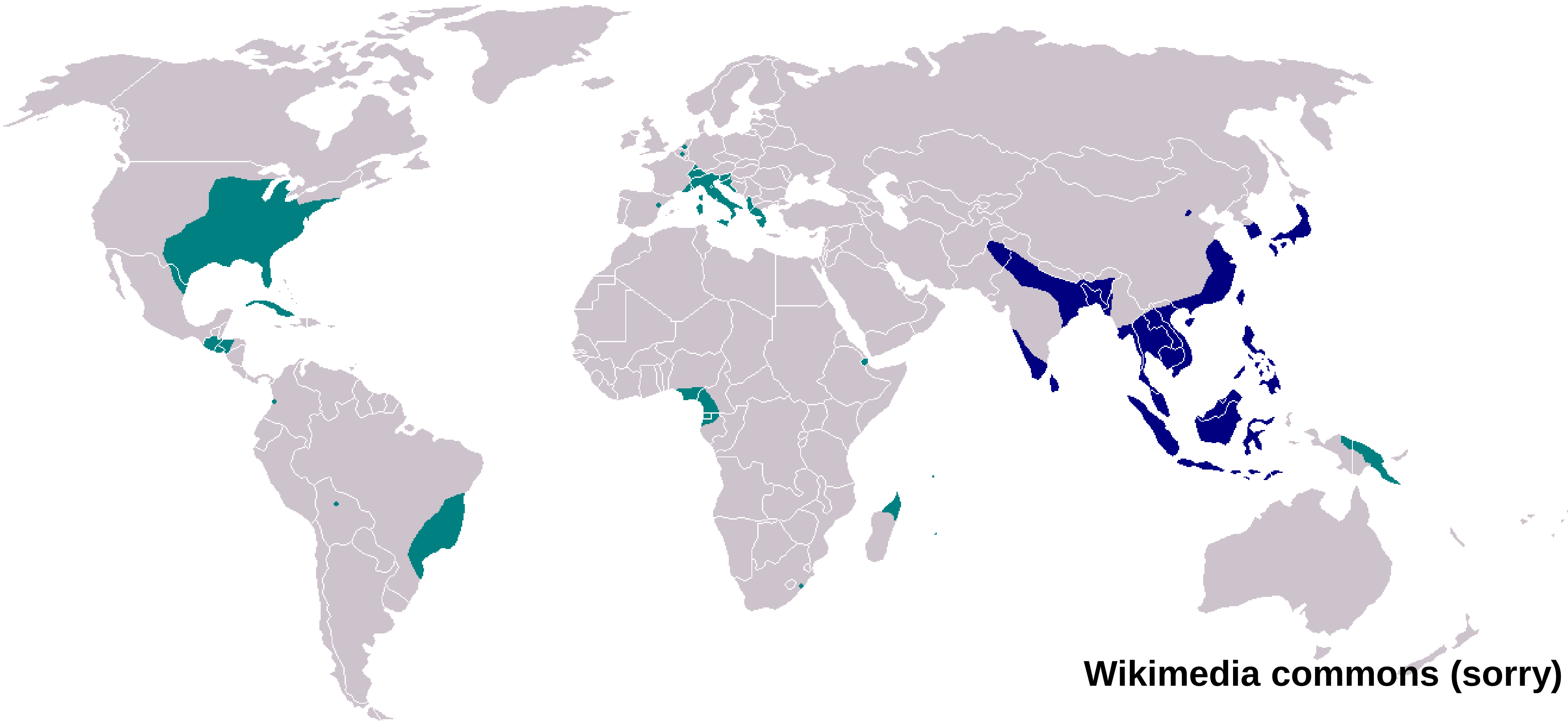
Asian tiger mosquito: distribution



Wikimedia commons (sorry)

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

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Asian tiger mosquito: Introduction routes

Scholte & Schaffner, 2007

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

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Asian tiger mosquito spread in Europe

Scholte & Schaffner, 2007

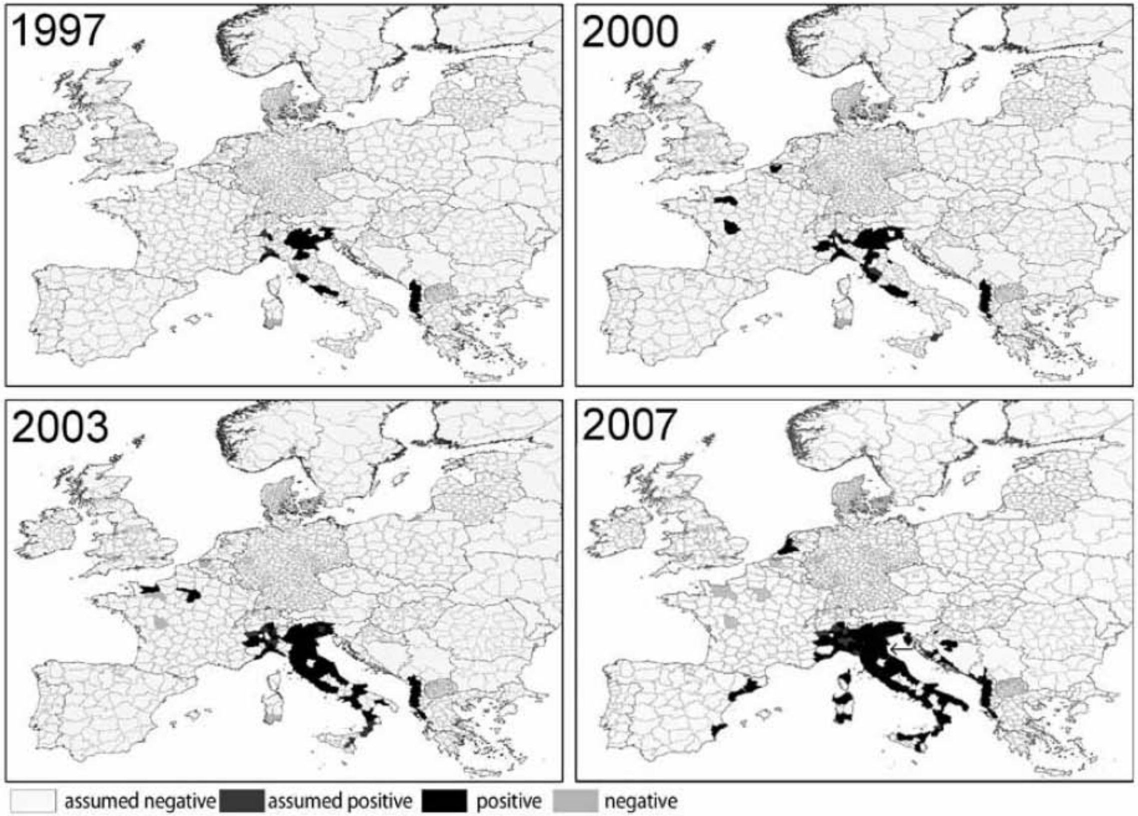

Figure 3. Presence of Aedes albopictus *in Europe per province for the years 1997-2007. Data to complete this figure were kindly made available by Roberto Romi (Italy), Roger Eritja and David Roiz (Spain), Eleonora Flacio (Switzerland), Charles Jeannin (France), Anna Klobučar (Croatia), Zoran Lukac (Bosnia 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.*

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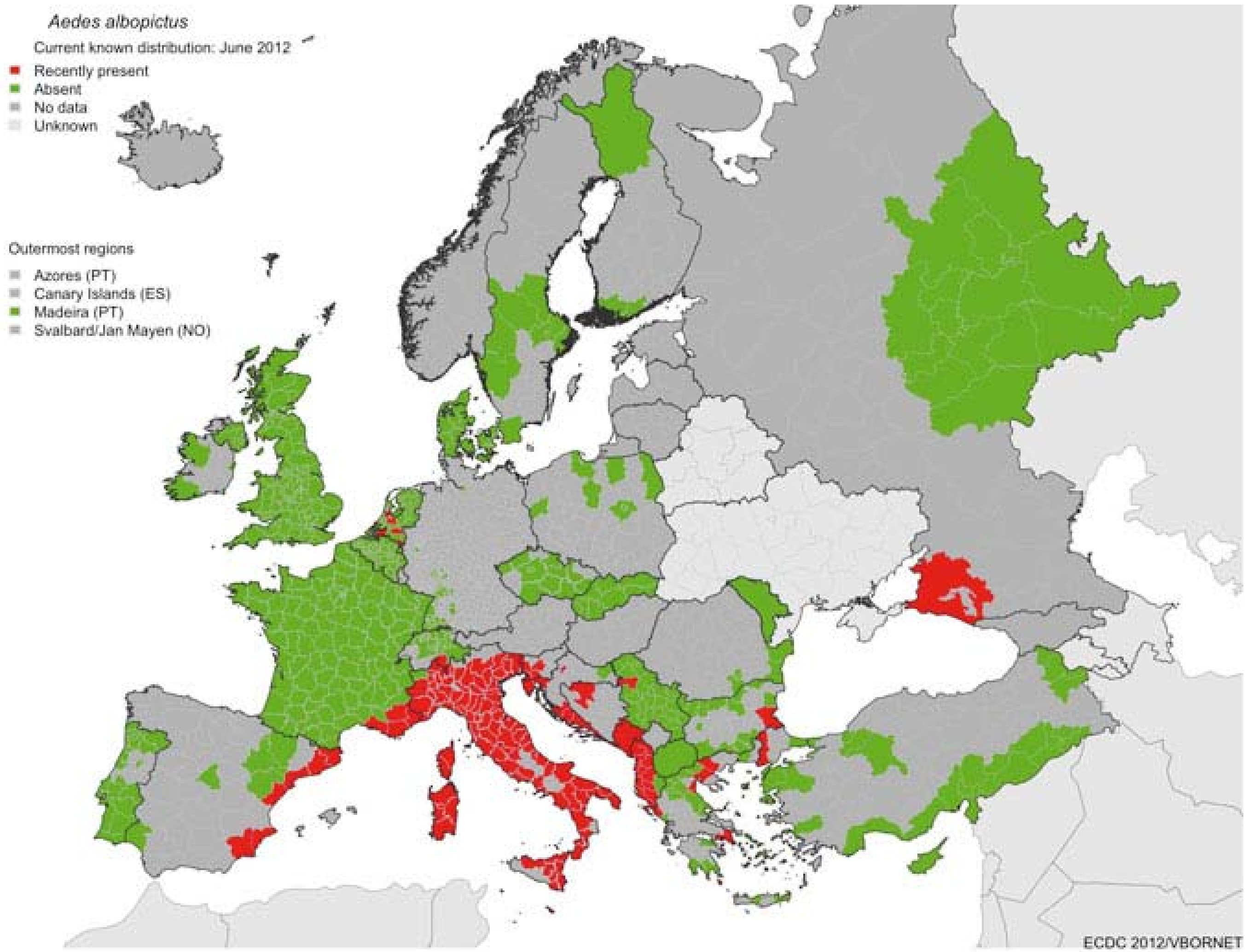
Asian tiger mosquito: distribution in Europe: ECDC/VBORNET framework Jan 2012



Hot spots:

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

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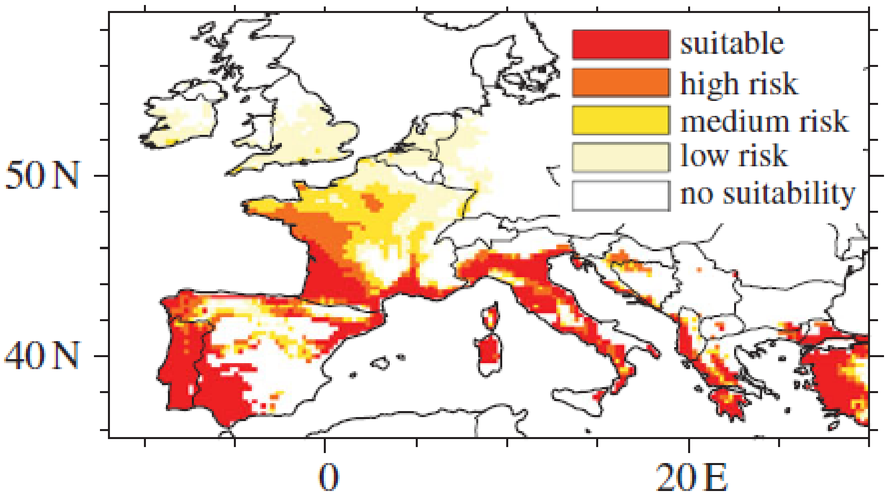
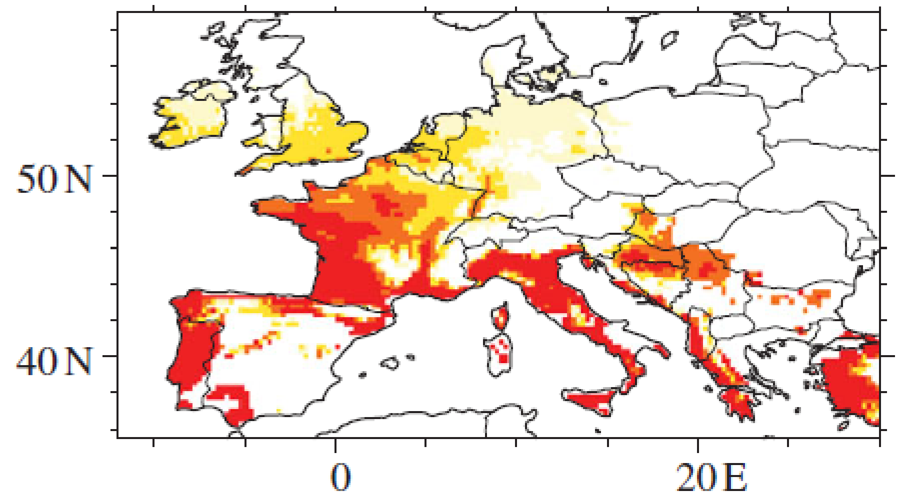
Simulated climate suitability for *A. albopictus*

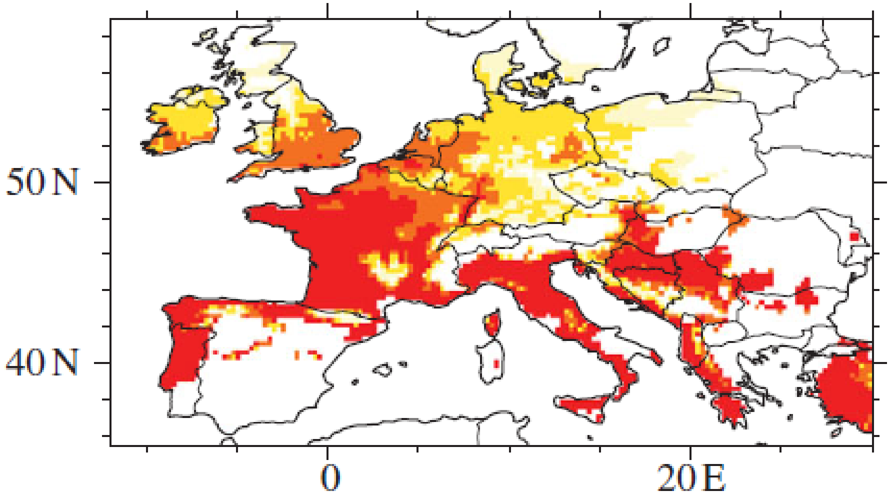
Climate obs 1960-1989



Climate obs 1990-2009



Climate Models 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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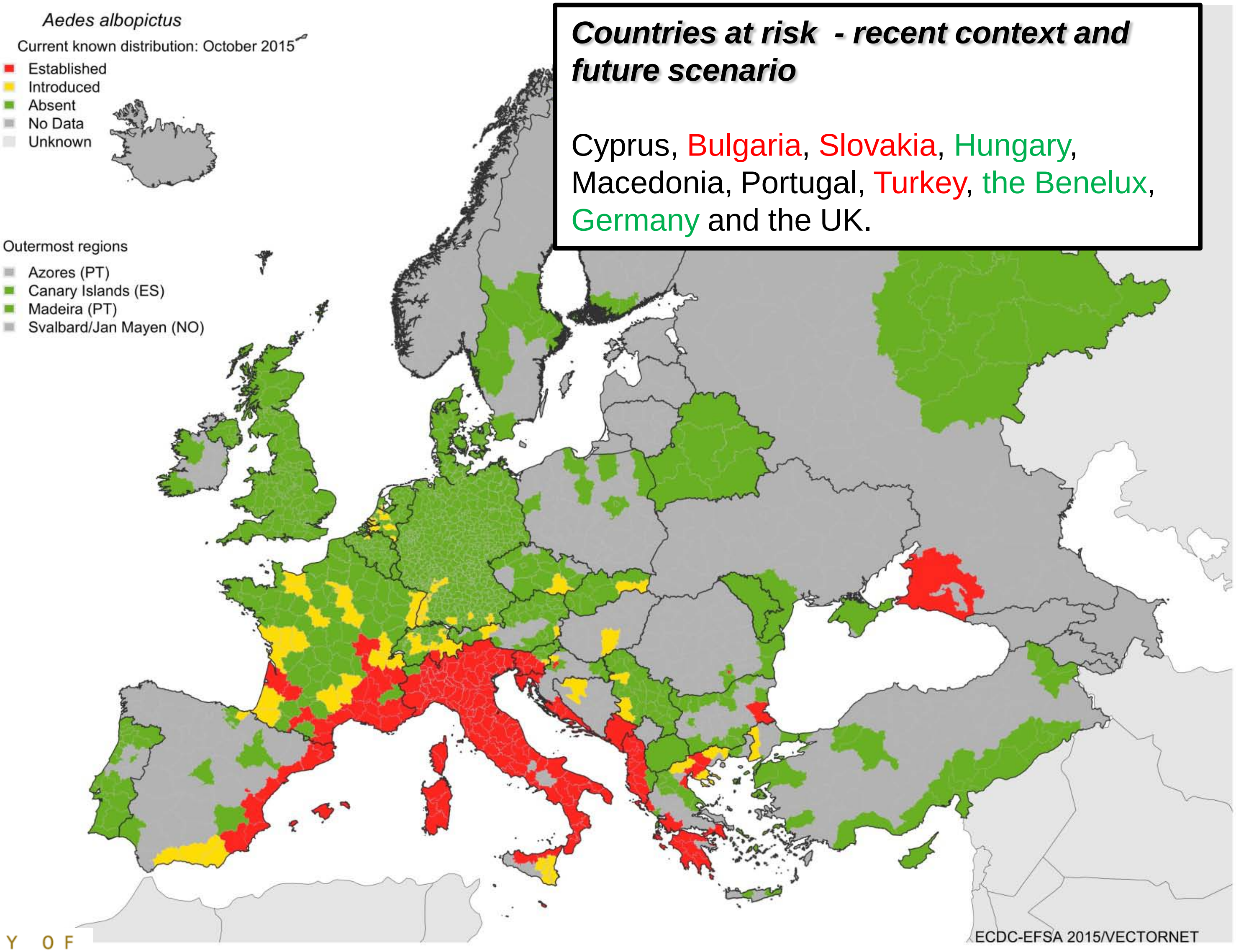
Asian tiger mosquito: distribution in Europe: ECDC/VBORNET October 2015



Countries at risk - recent context and future scenario

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

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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

SANTÉ

Gare aux allergies et aux moustiques

Profitant de la chaleur, les plantes allergisantes et les insectes vecteurs de maladies exotiques vont conquérir l'Hexagone.

Vagues de chaleur, allergies et maladies exotiques risquent d'être notre lot commun dans les décennies à venir, comme l'a établi la conférence internationale du GIS* en octobre 2014. « *Les vagues de chaleur vont s'accroître en fréquence, durée et amplitude* », assure Robert Vautard, directeur du Laboratoire des sciences du climat et de l'environnement (LSCE) au CEA, à Saclay.

Une vague de chaleur se définit comme une période de plusieurs jours durant laquelle les (hautes) températures ne redescendent pas durant la nuit. En 2003, la canicule avait provoqué le décès de 15 000 personnes en France. « *Une dizaine de modèles informatiques prédisent des zones touchées plus ou moins étendues selon les paramètres de calcul* », poursuit Robert Vautard. Quel que soit le modèle, c'est le Sud-Est qui va le plus souffrir ainsi que les régions continentales. Les sols secs de l'intérieur des terres renverront l'énergie solaire sous forme de chaleur, amplifiant le phénomène. Les grands gagnants de cette élévation thermique seront certains végétaux. C'est ainsi qu'on prévoit la forte expansion d'*Ambrosia artemisiifolia*, espèce invasive d'Amérique du Nord dont les pollens très allergisants provoquent rhinites, conjonctivites, trachéites et crises d'asthme. « *La période végétative démarrera plus tôt et, en raison d'un effet fertilisant du CO, les pollens seront plus abondants* », souligne Nicolas Viovy, chercheur au LSCE.

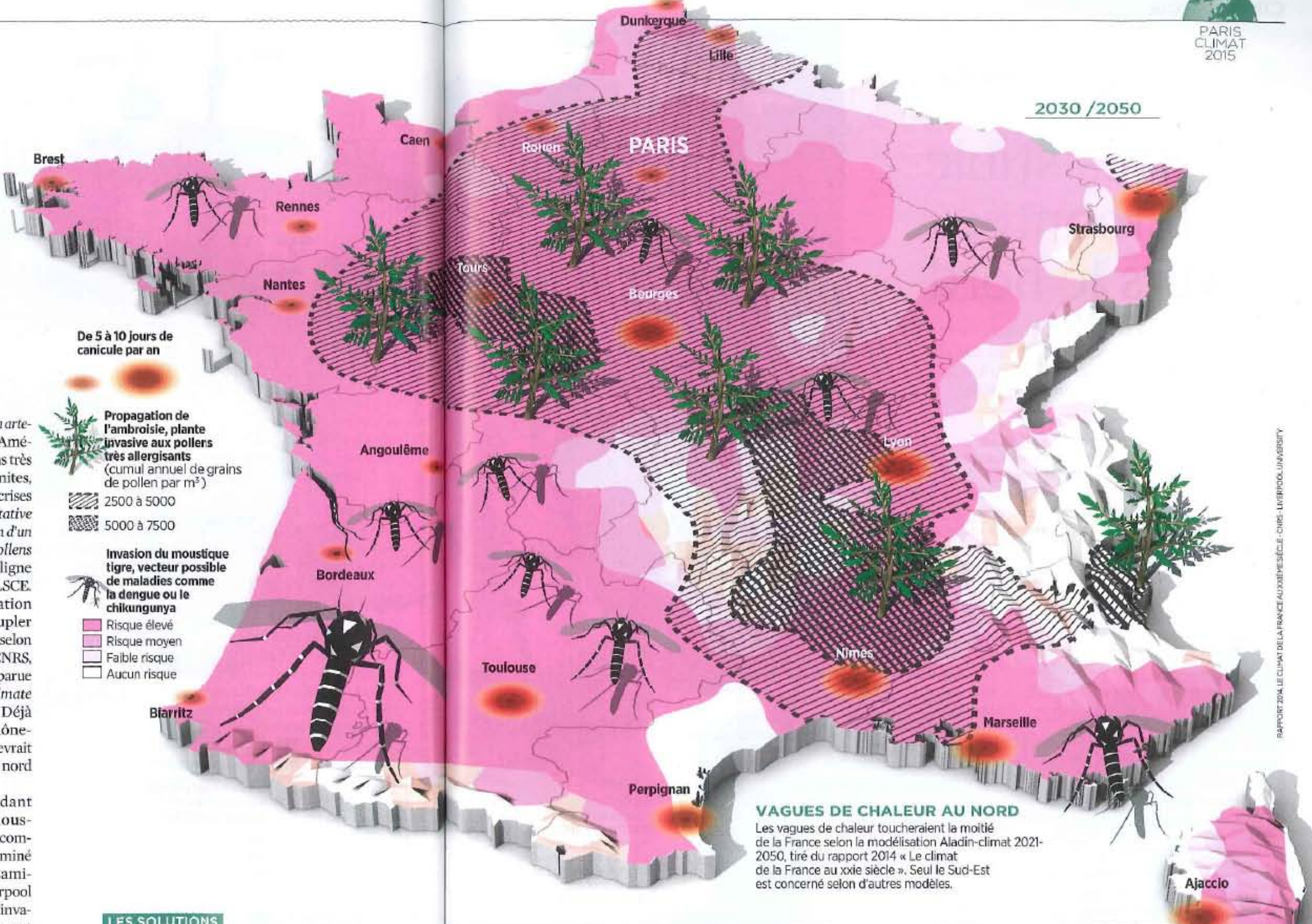
> L'ambroisie, qui provoque rhinites et crises d'asthme, sera en forte expansion

Leur concentration pourrait quadrupler à l'horizon 2050, selon l'étude Atopica (CNRS, Ineris et RNSA), parue dans *Nature Climate Change* en mai. Déjà présente en Rhône-Alpes, la plante devrait s'étendre vers le nord de la France.

Son avancée sera cependant moindre que celle du moustique tigre, introduit par le commerce international et disséminé par les transports. Cyril Caminade, de l'université de Liverpool (Royaume-Uni) a modélisé l'invasion de l'insecte potentiellement porteur de maladies telles que la dengue ou le chikungunya. En 2050, il bourdonnerait sur tout le territoire, sauf en montagne. ■

Elena Sender
@Elenasender

* Groupement d'intérêt scientifique (CNRS, CEA, UVSQ, UPMC, École polytechnique, Ademe).



VAGUES DE CHALEUR AU NORD
Les vagues de chaleur toucheraient la moitié de la France selon la modélisation Aladin-climat 2021-2050, tiré du rapport 2014 « Le climat de la France au xxie siècle ». Seul le Sud-Est est concerné selon d'autres modèles.

RAPPORT 2014, LE CLIMAT DE LA FRANCE AU XXIe SIÈCLE - CNRS - LIVERPOOL UNIVERSITY

LES SOLUTIONS

Prévenir les contaminations

MESURES Des affichages dans les aéroports sensibiliseront les voyageurs de retour de pays tropicaux aux symptômes (fièvres, douleurs articulaires). Les vases et conteneurs d'eau à l'extérieur devront être vidés, et il faudra porter des vêtements longs et utiliser des produits antimoustiques. À noter, seuls les moustiques tigres qui ont piqué un humain porteur de la dengue ou du chikungunya, peuvent transmettre la maladie.

Rafraîchir les villes

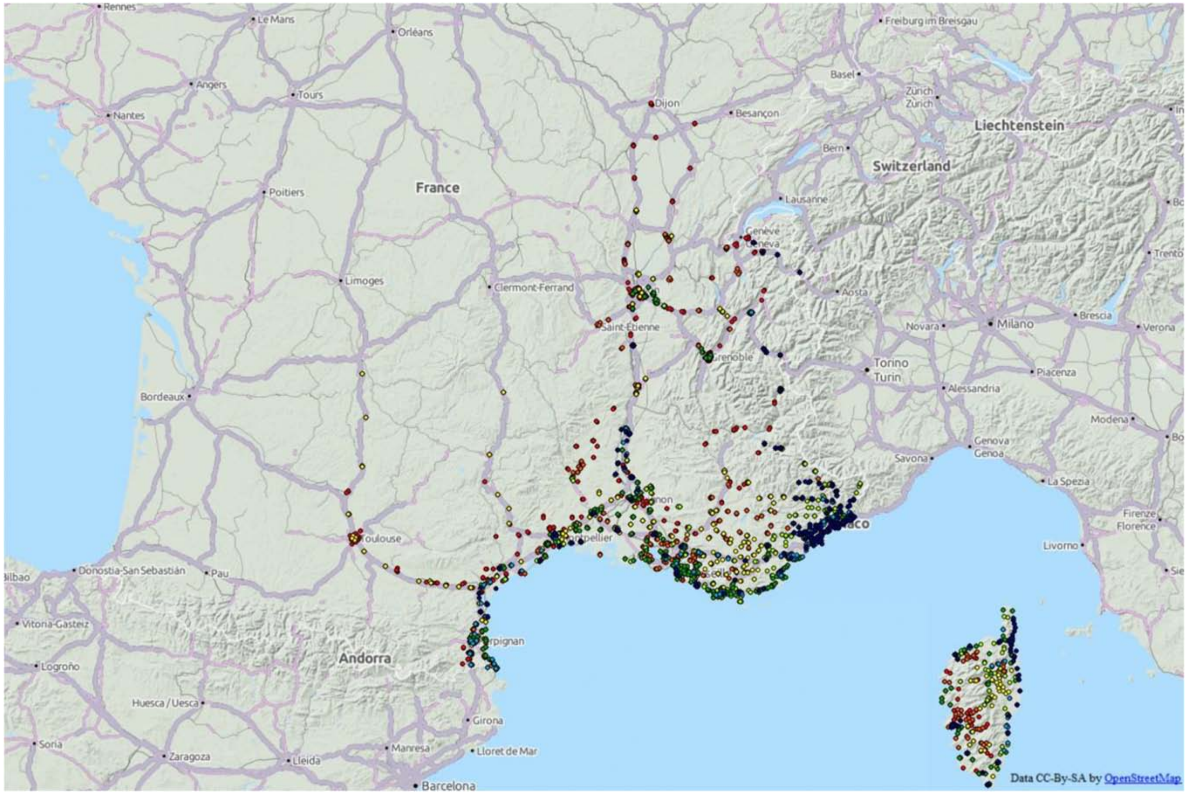
URBANISATION. La réhabilitation thermique des bâtiments devra être améliorée. L'espace public devra être davantage végétalisé. L'utilisation de l'eau de la ville comme thermorégulation permettra de limiter les pics de chaleur en zone urbaine dense, de réduire les températures nocturnes et de procurer de la fraîcheur durant la journée.

Lutter contre les effets des pollens

TRAITEMENTS. L'élimination des espèces invasives comme l'ambroisie à feuille d'armoise pourra être effectuée par des campagnes d'arrachage. Il faudra éviter les zones à forte densité de pollens en période défavorable (sèche et sans vent) et prendre des antihistaminiques en cas de forte concentration. Les autorités devront multiplier des bulletins de prévision et d'alerte comme pour la pollution.

Sciences et Avenir 821 – Juillet 2015

Spread in France? Hitchhiker mosquitoes?



Roche et al., 2015

Green, yellow, blue, red, orange are the traps collected in 2006, 2007, 2008, 2009, 2010 respectively

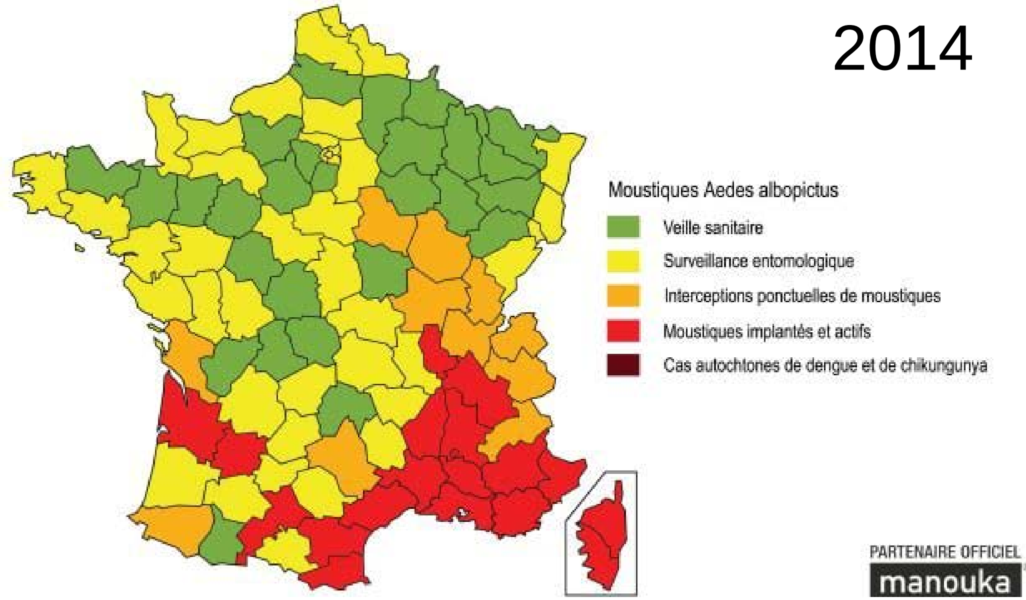
We transport them, convenient given the quality of our highways!

Human activities are especially important for mosquito dispersion while land use is a major factor for mosquito establishment.
Ae. *albopictus* invasion is accelerating through time in this area, resulting in a geographic range extending further and further year after year.
Sporadic “jump” of *Ae*. *albopictus* in a new location far from the colonized area did not succeed in starting a new invasion front so far.

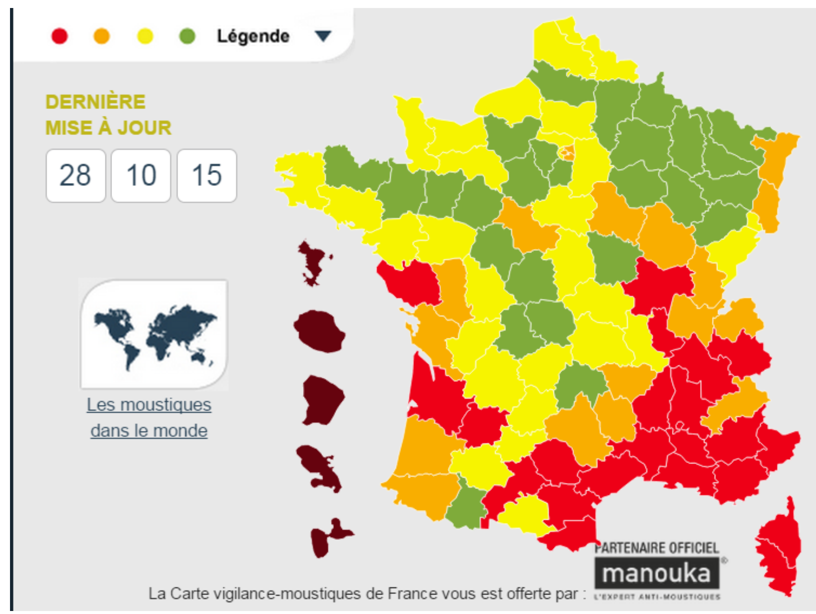
Recent distribution in France

Carcassonnes airport, summer 2014

2014



2015



Risk of autochthonous transmission of chikungunya and dengue viruses posed by infected travellers returning home !

In the french news recently (and elsewhere…)

LADEPECHE.fr

mardi 06 octobre, 16:21, Saint Bruno

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La Santé près de chez vous · Actu Santé · Psycho - Sexo · Beauté · Bien-être · Nutrition · Famille · Dictionnaires

You don't just choose the OU's Open degree.

Actualité > Grand Sud > Tarn > Santé

Le moustique tigre est dans le Tarn

Publié le 07/09/2015 à 03:50, Mis à jour le 07/09/2015 à 07:56

Moustique tigre - Santé

Le moustique tigre est officiellement implanté dans le … chikungunia./Photo DDM.

Un arrêté ministériel vient d'ajouter le Tarn à la lis… moustique tigre, un insecte potentiellement porteu…

En images

LADEPECHE.fr

mardi 06 octobre, 16:07, Saint Bruno

autour de bébé BLAGNAC - COLOMIERS - PORTET

Actualités > Santé > Actu Santé

Trois nouveaux cas de dengue à Nîmes

Publié le 08/09/2015 à 20:25

Actu Santé

La dengue, qui se transmet à l'homme uniquement par une piqûre du moustique tigre (Aedes… en métropole, est une maladie généralement bénigne qui entraîne des complications dans en… des cas. RelaxNews / PASCAL GUYOT / AFP

(AFP) - Trois nouveaux cas autochtones de dengue, une maladie transmise par le m… tigre, ont été diagnostiqués dans un quartier du sud-est de Nîmes, où deux malades…

LADEPECHE.fr

mercredi 28 octobre, 17:40, Saint Simon

71e FOIRE DE LA COLOMBETTE DU VENDREDI 30 OCTOBRE AU DIMANCHE 1er NOVEMBRE 10H00 19H00

Actualité > Grand Sud > Haute-Garonne > Santé

Alerte rouge au moustique tigre en Haute-Garonne

Publié le 01/08/2015 à 03:49, Mis à jour le 01/08/2015 à 07:58

Moustique tigre - Le fait du jour

Alerte rouge au moustique tigre en Haute-Garonne

La Haute-Garonne est placée en «surveillance renforcée», alerte rouge, concernant la prolifération du moustique tigre, vecteur de maladies virales.

Originaire d'Asie, le moustique tigre empoisonne le département de la Haute-Garonne depuis presque trois ans.

En images

Miss France-2016 : les 31 candidates en images

Galerie Marchande Ccial Leclerc Saint Orens

» En savoir plus.

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 (low immunity e.g. susceptible population)
- 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 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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A bit of history

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

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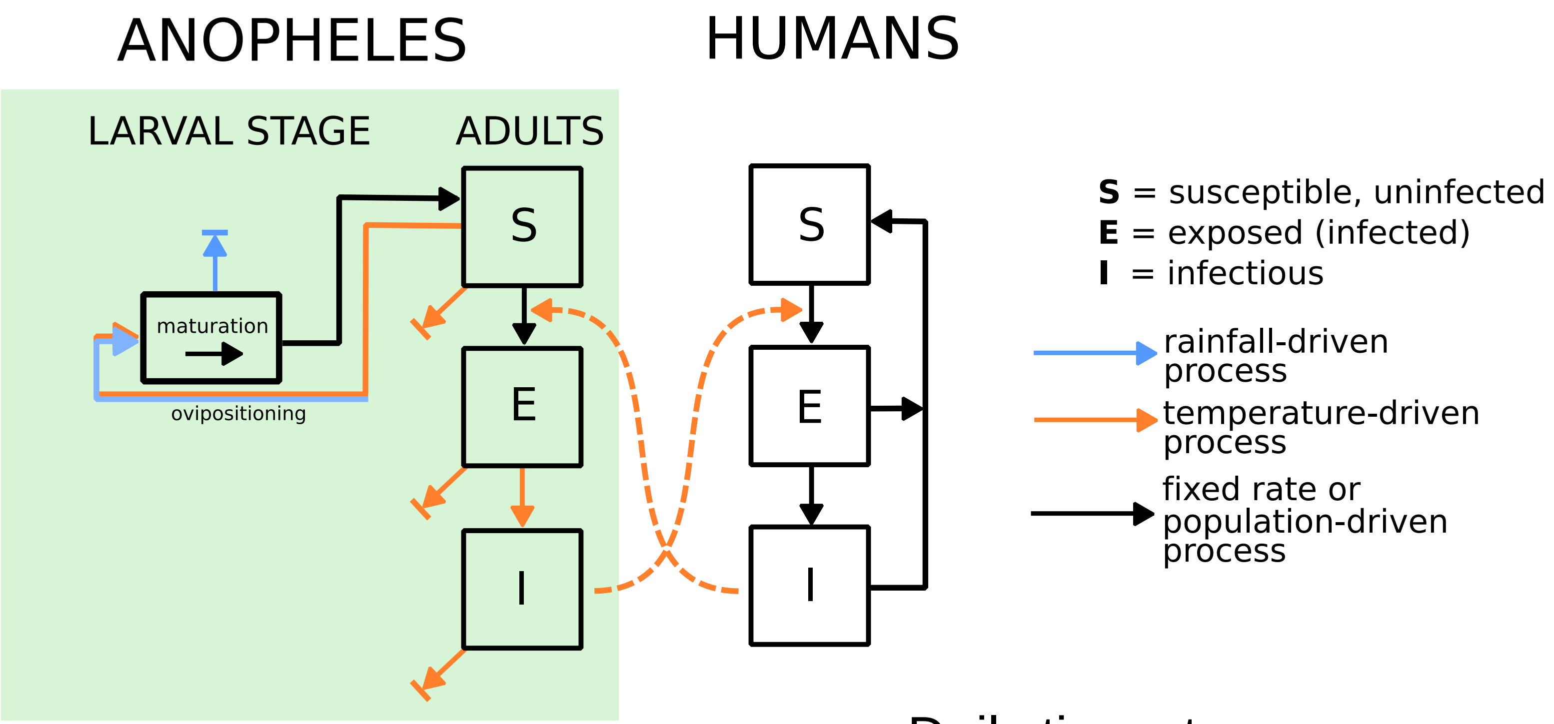
Malaria Distribution 1948

Source: WHO

The Liverpool Malaria Model



Hoshen and Morse, 2004

Key difference from Aron & May basic model is temperature-dependent latent period in mosquito (sporogonic cycle) which requires T>18^{o}C

Daily time step

Climate drivers:

•10 day accumulations of rainfall

•Temperature

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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 (**health**, agriculture, water ressources)*

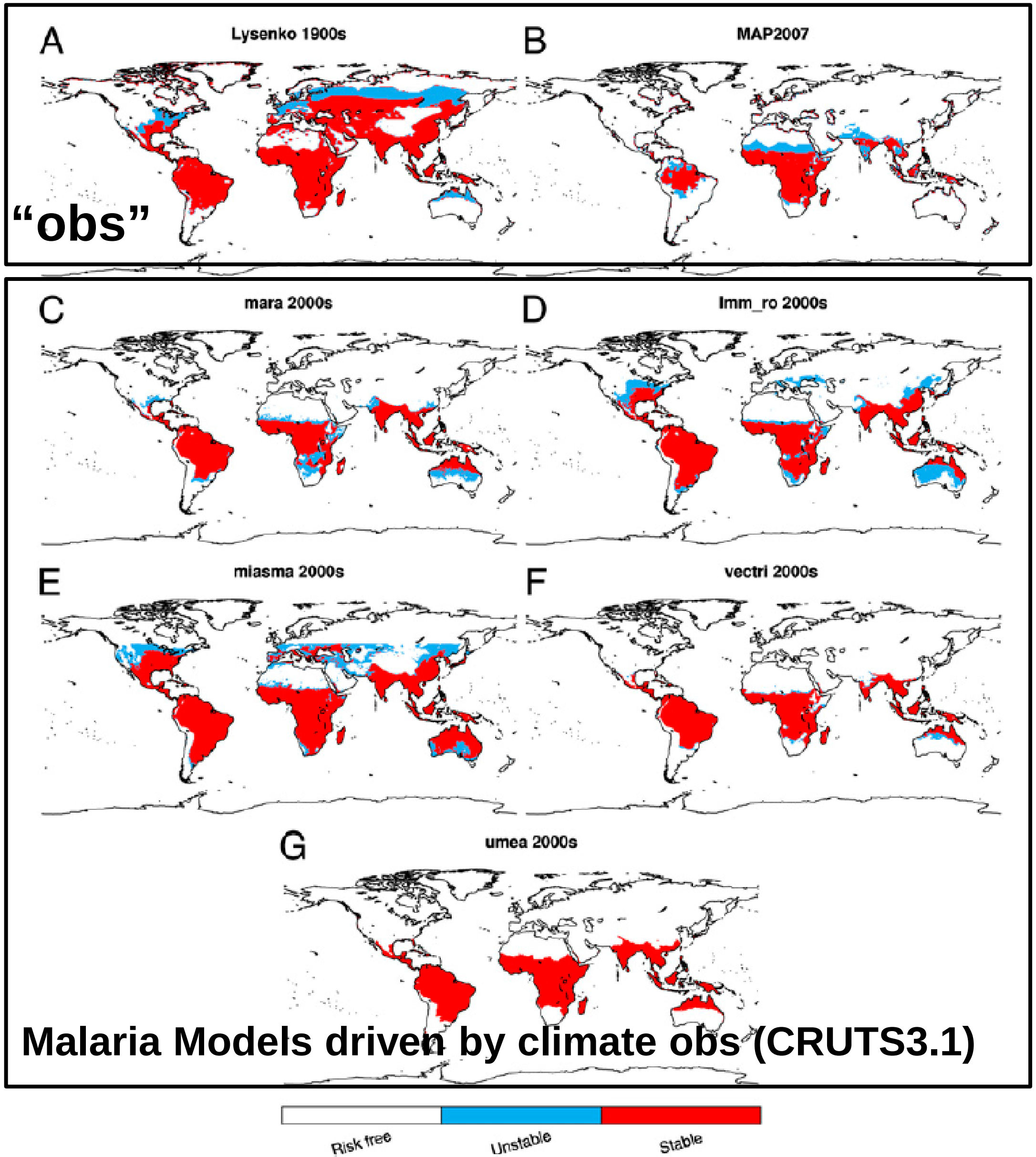
Five malaria models investigated: MARA, LMM_ro, Vectri, Umea & MIASMA

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

Bias corrected climate scenarios were available for **5 emission scenarios** [2.6, 4.5, 6, 8.5] emission scenarios and the historical simulations for **5 climate models. One Population scenario SSP2 (IAASA)**

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

Malaria Background 1900s vs 2000s

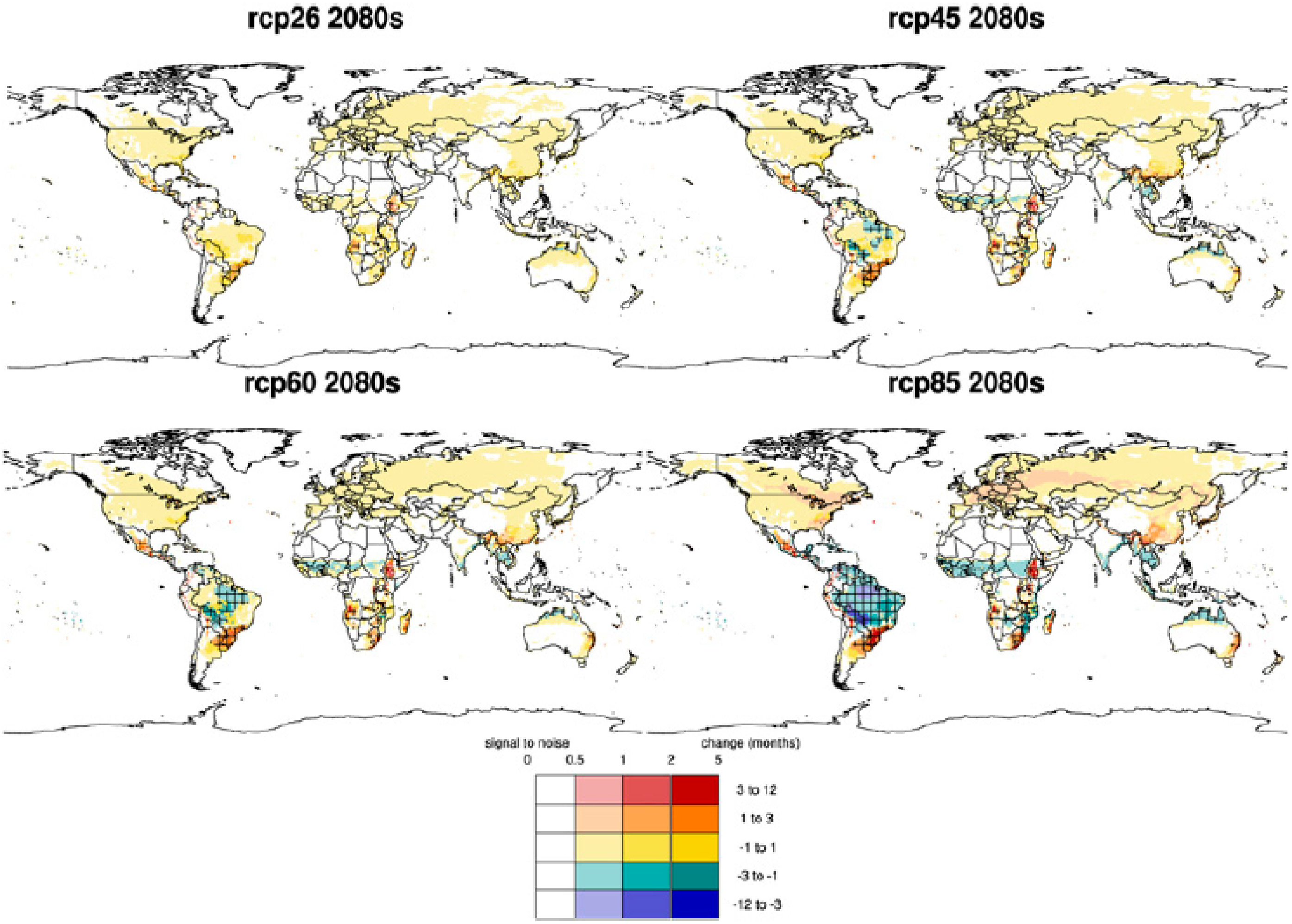


Malaria endemicity decreased worlwide
Mainly due to intervention (bed nets, early diagnostic tests, vector control…)

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

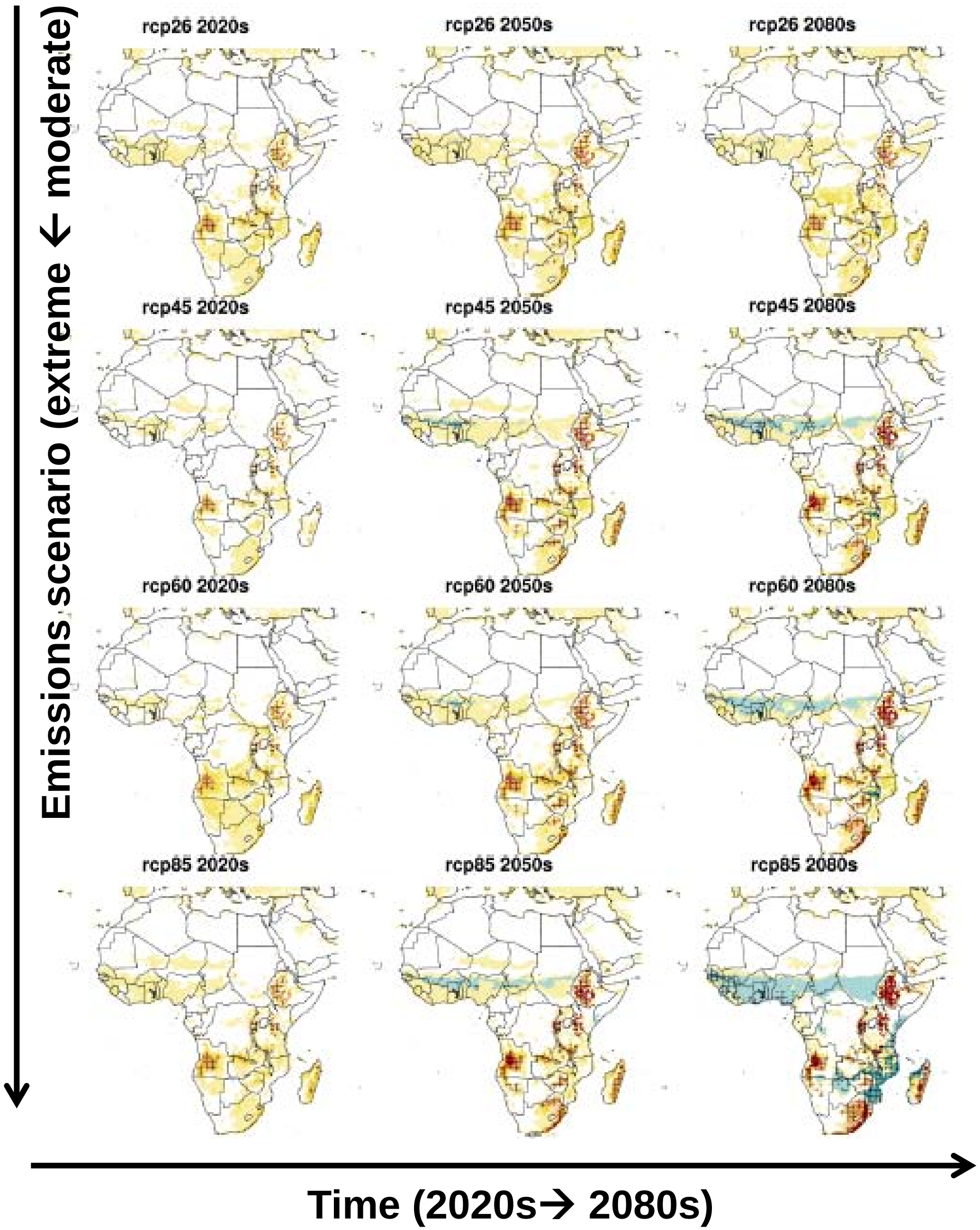
Impact of climate change on malaria distribution



Climatic suitability simulated to increase for all malaria models over the Tropical highland regions and to decrease over low altitude regions for the 2080s (extreme emission scenario).

Caminade et al., 2014

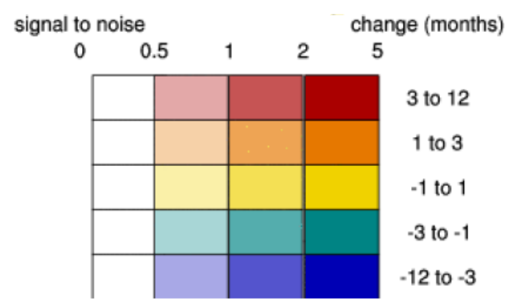
Malaria 21st century scenario



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)



Malaria scenarios for Eastern Africa: the HEALTHY FUTURES EU project

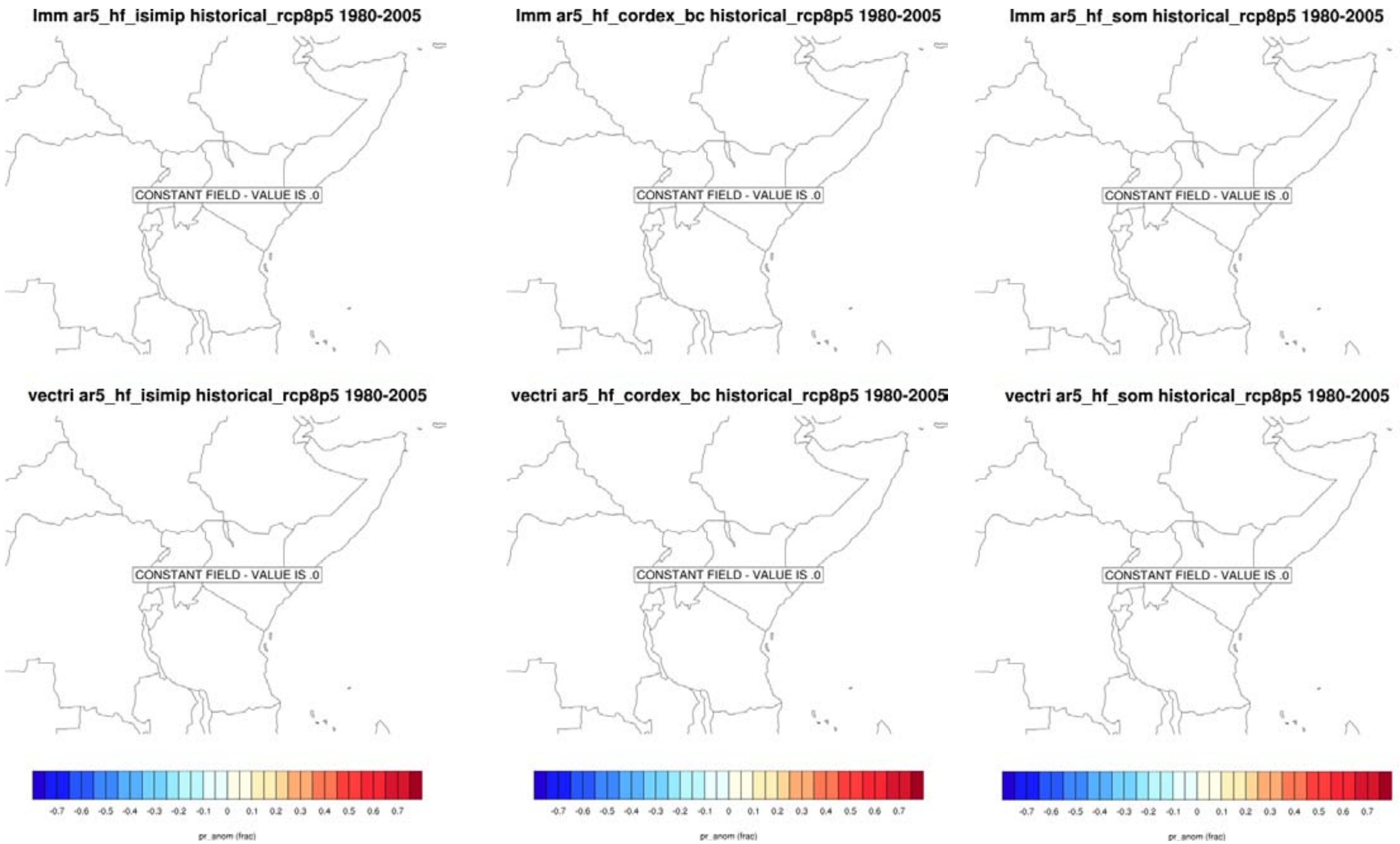
ISI-MIP
5 GCMs

CORDEX
8 RCMs

CMIP5
10 GCMs

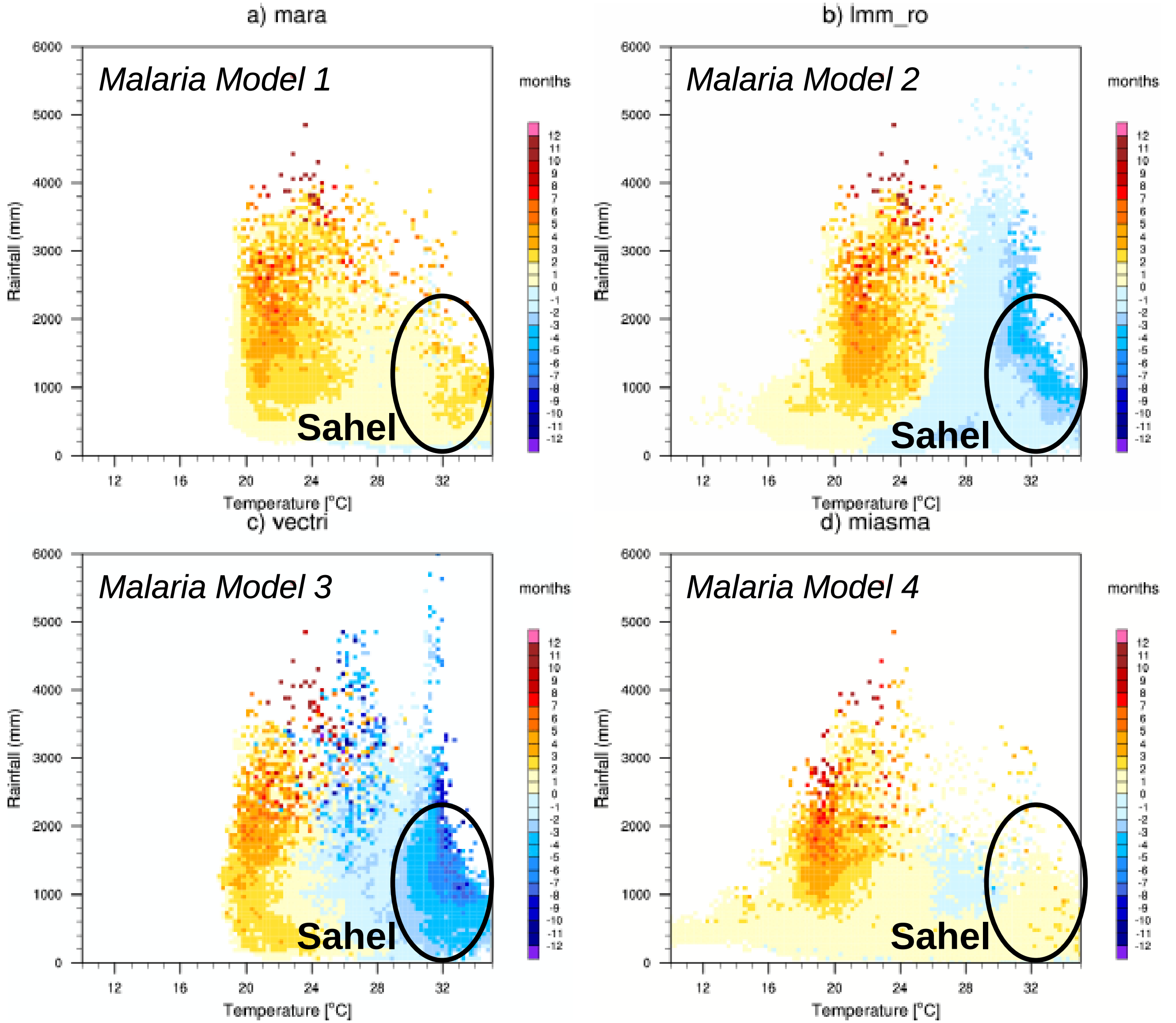
LMM
malaria model

VECTRI
malaria model



Changes in simulated malaria prevalence based on two malaria models and different GCM/RCM ensembles (RCP8.5 from 1980-2005 to 2086-2095). Ensemble mean is shown
Leedale et al., 2015 (Geo. Sp. Health, in review)

Malaria models sensitivity in a warmer world



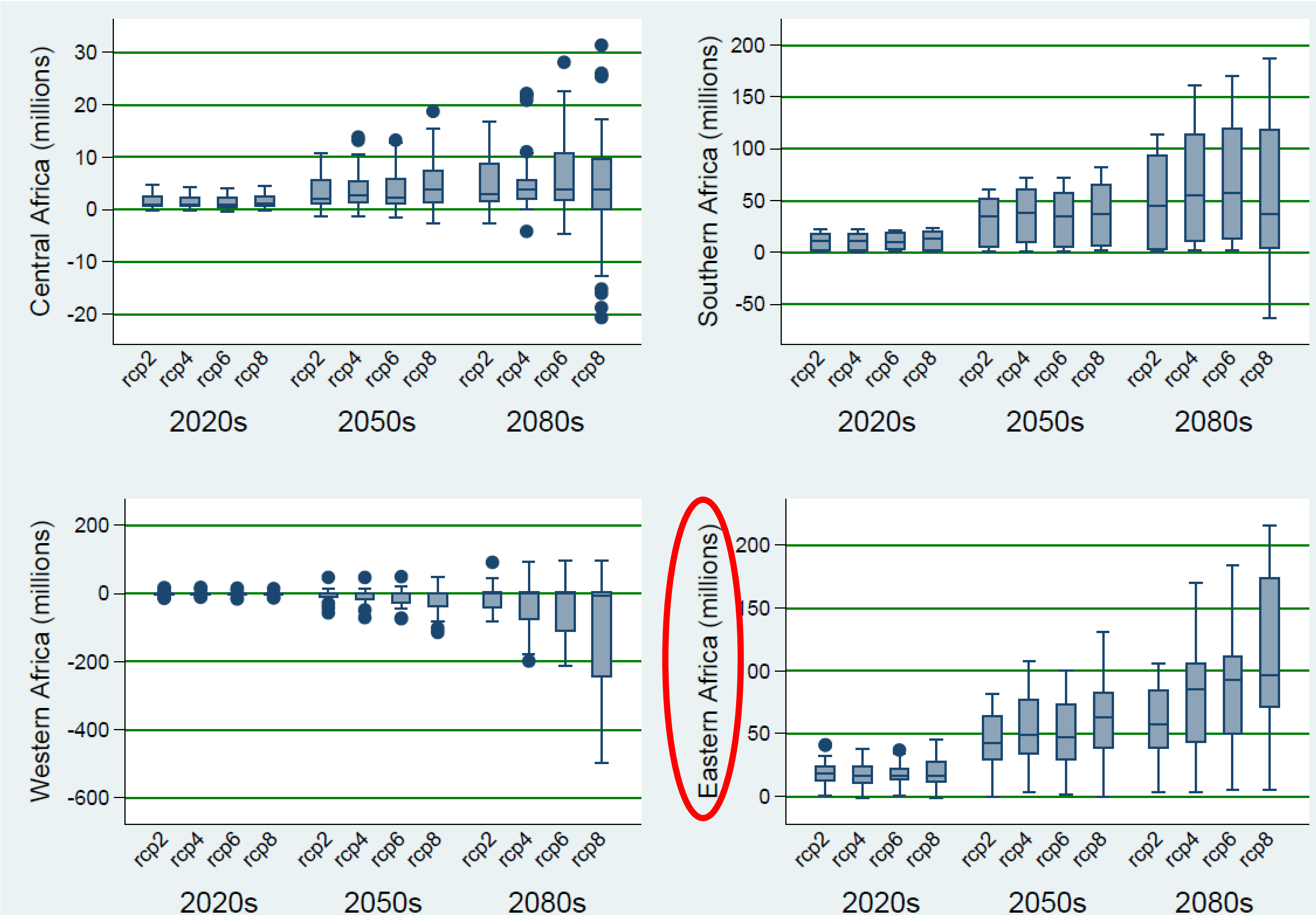
Sensitivity of the simulated changes in the length of the malaria transmission season (LTS) to mean annual rainfall and temperature for the ISI-MIP ensemble over Africa.

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

Mara, miasma: General Increase in LTS

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

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

From the category...

Global University
Press Release
Research
University Life

Tagged with...

Climate Change
Dr Cyril Caminade
environmental-sciences
Faculty of Science and Engineering
global warming
Infection and Global Health
Institute of Infection and Global Health
malaria
School of Environmental Sciences

Recent Stories

Viewpoint: Floods – learning from the past

More recent scientific evidences that malaria is moving to higher altitude & latitude

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.

Dhimal *et al. Malaria Journal* 2014, **13**(Suppl 1):P26
http://www.malariajournal.com/content/13/S1/P26

MALARIA JOURNAL

POSTER PRESENTATION **Open Access**

Altitudinal shift of malaria vectors and malaria elimination in Nepal

Meghnath Dhimal[1,2]*, Bodo Ahrens[2,3], Ulrich Kuch[4]

From Challanges in malaria research: Core science and innovation
Oxford, UK. 22-24 September 2014

Acta Tropica xxx (2013) xxx–xxx

Contents lists available at SciVerse ScienceDirect

Acta Tropica

journal homepage: www.elsevier.com/locate/actatropica

ELSEVIER

A first report of *Anopheles funestus* sibling species in western Kenya highlands

Eliningaya J. Kweka[a,b,*], Luna Kamau[c], Stephen Munga[b], Ming-Chieh Lee[d], Andrew K. Githeko[b], Guiyun Yan[d]

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[b] Centre for Global Health Research, Kenya Medical Research Institute, P.O. Box 1578, Kisumu, Kenya
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[d] Program in Public Health, University of California, Irvine, CA 92697, USA

Dhimal *et al. Parasites & Vectors* 2014, **7**:540
http://www.parasitesandvectors.com/content/7/1/540

Parasites & Vectors

RESEARCH **Open Access**

Species composition, seasonal occurrence, habitat preference and altitudinal distribution of malaria and other disease vectors in eastern Nepal

Meghnath Dhimal[1,2,3,4*], Bodo Ahrens[2,3] and Ulrich Kuch[4]

OPEN ACCESS Freely available online

PLOS | ONE

First Evidence and Predictions of *Plasmodium* Transmission in Alaskan Bird Populations

Claire Loiseau[1]*, Ryan J. Harrigan[2], Anthony J. Cornel[3], Sue L. Guers[4], Molly Dodge[1], Timothy Marzec[1], Jenny S. Carlson[3], Bruce Seppi[5], Ravinder N. M. Sehgal[1]

More scientific evidences that climate becomes increasingly suitable for malaria in Tropical highland regions BUT other parameters will be critical:

Population movements, trade and urbanisation (expected to increase…)

Technological development (vector control, vaccine?)

Land surface changes (agriculture: fisheries, rice paddies… expected to change significantly in developing countries)

Adaptation and evolution (mosquitoes resistance to insecticide, pathogen resistance to drugs…). Drug resistance on the rise for many pathogens

Socio-economic development (changes in wealth and vulnerability)

Indirect effects of climate change…

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

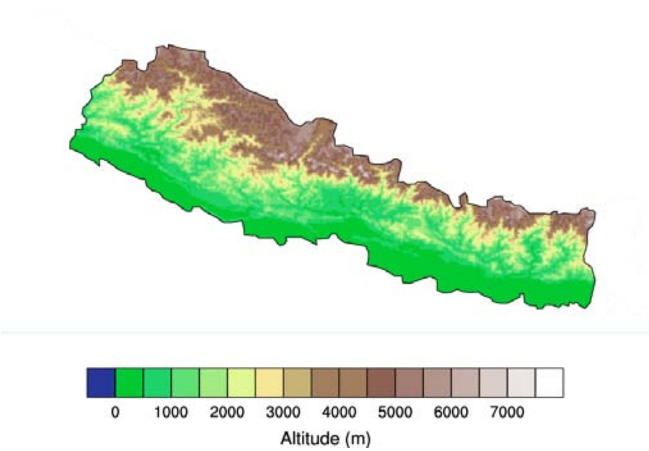
EVOLUTION OF MALARIA IN AFRICA FOR THE PAST 40 YEARS: IMPACT OF CLIMATIC AND HUMAN FACTORS

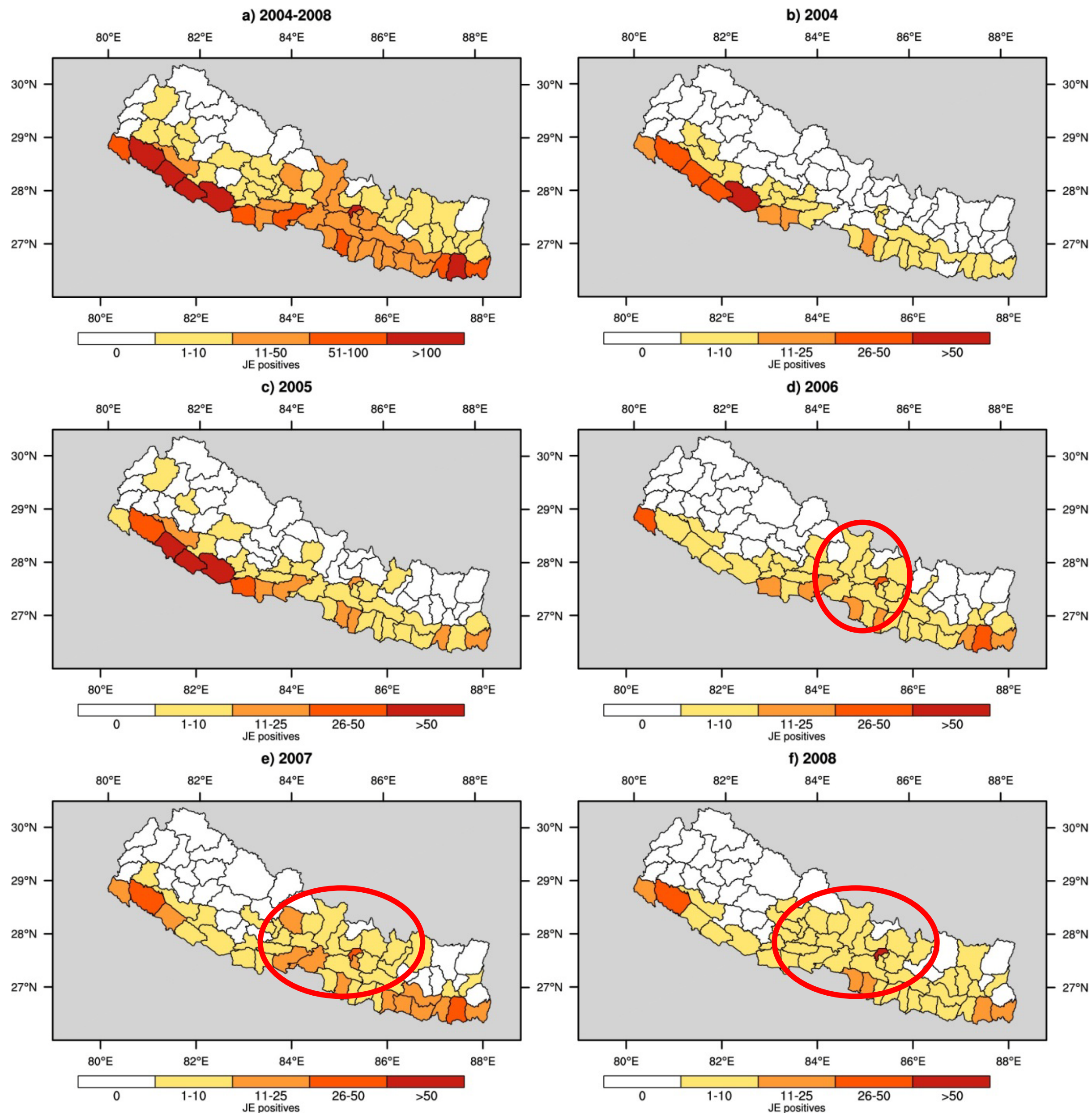
JEAN MOUCHET,[1] SYLVIE MANGUIN,[2] JACQUES SIRCOULON,[1] STÉPHANE LAVENTURE,[3] OUSMANE FAYE,[4] AMBROSE W. ONAPA,[5] PIERRE CARNEVALE,[6] JEAN JULVEZ[7] AND DIDIER FONTENILLE[8]

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

Not only malaria moving to higher grounds…
Japanese encephalitis in Nepal 2004-2008

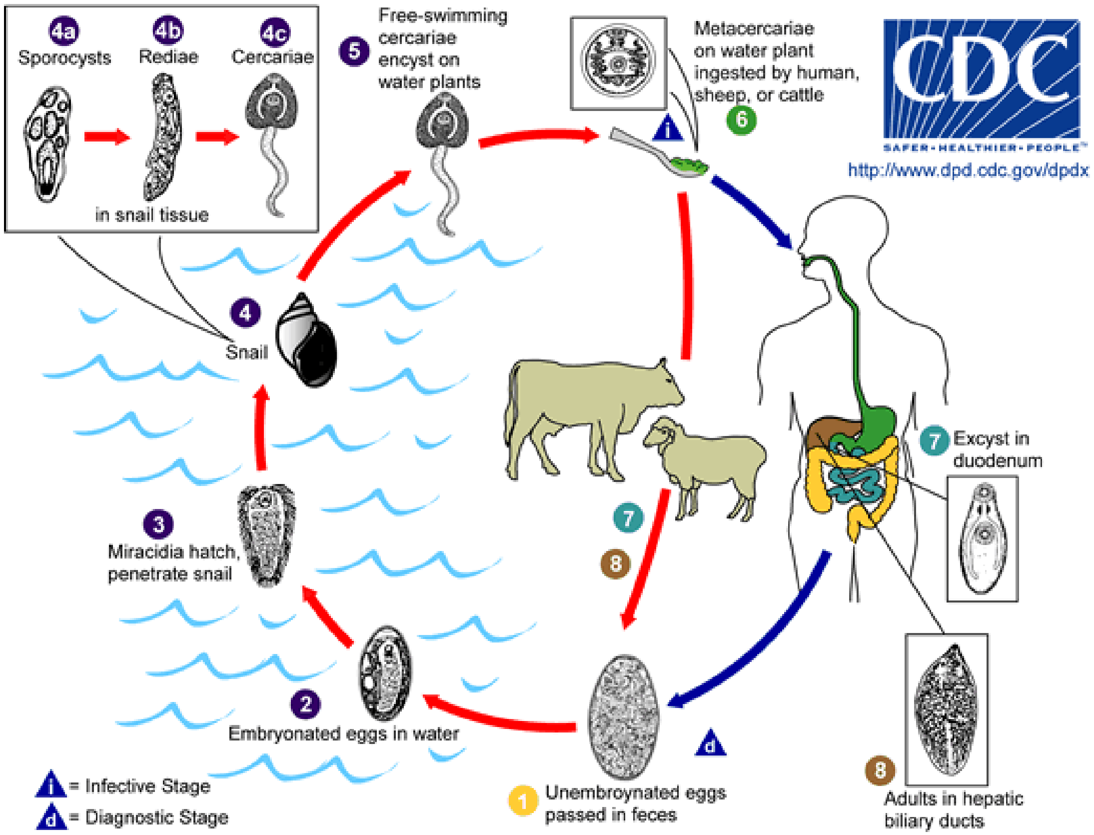




Increase of autochthonous disease transmission to non endemic regions (>2000m) in Nepal:

Japanese encephalitis
Malaria
Dengue fever
Lymphatic filiarisis
Visceral leishmaniasis
(Dhimal et al., 2015, PlosOne)

Fasciola hepatica and its impacts



Fasciola hepatica, also known as the **common liver fluke** or **sheep liver fluke** is a parasitic flatworm of the class Trematoda, infects liver of various mammals, including humans.

The disease caused by the fluke is called fascioliasis (also known as fasciolosis). Its life cycle requires a fresh water snail as intermediate host (wet grassland settings).

F. hepatica is world-wide distributed and causes great economic losses in sheep and cattle.

Increasing burden over the UK and other European countries over the past decades-> Gloworm EU project

Liver of a sheep
Infected by Fasciola hepatica

Fasciolosis Model (1/2)

Monthly *fasciola hepatica* risk (Mt) :

$$Mt = n\left(\frac{R}{25.4} - \frac{P}{25.4} + 5\right)$$

How wet
vs how warm
are the soils?

R: Rainfall (mm/month)
P: Potential evapotranspiration (mm/month)
N: Number of rainy days per month

P was calculated using the Hargreaves equation:

$$P = 0.0023 * 0.408 * Ra\left(\frac{T\max + T\min}{2} + 17.8\right)\sqrt{T\max - T\min}$$

With Ra incoming extraterrestrial radiation in [MJm-2day-1]
Ra=F(latitude, day of year)
Mt capped between 0 and 100; Mt =0 if T<10ºC

Ollerenshaw & Rollands, 1959

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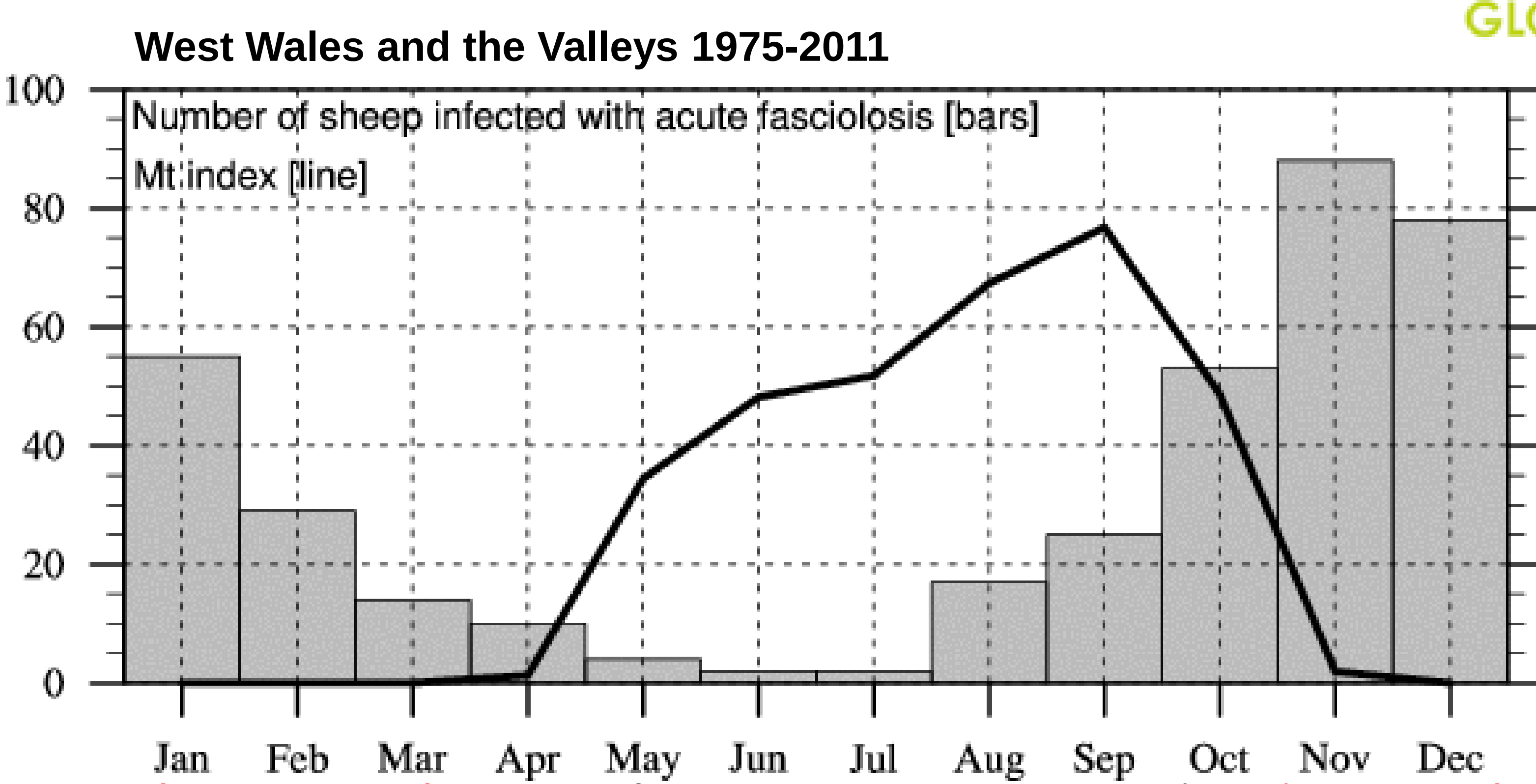
Fasciolosis Model (2/2)



Summer infections (acute or chronic)

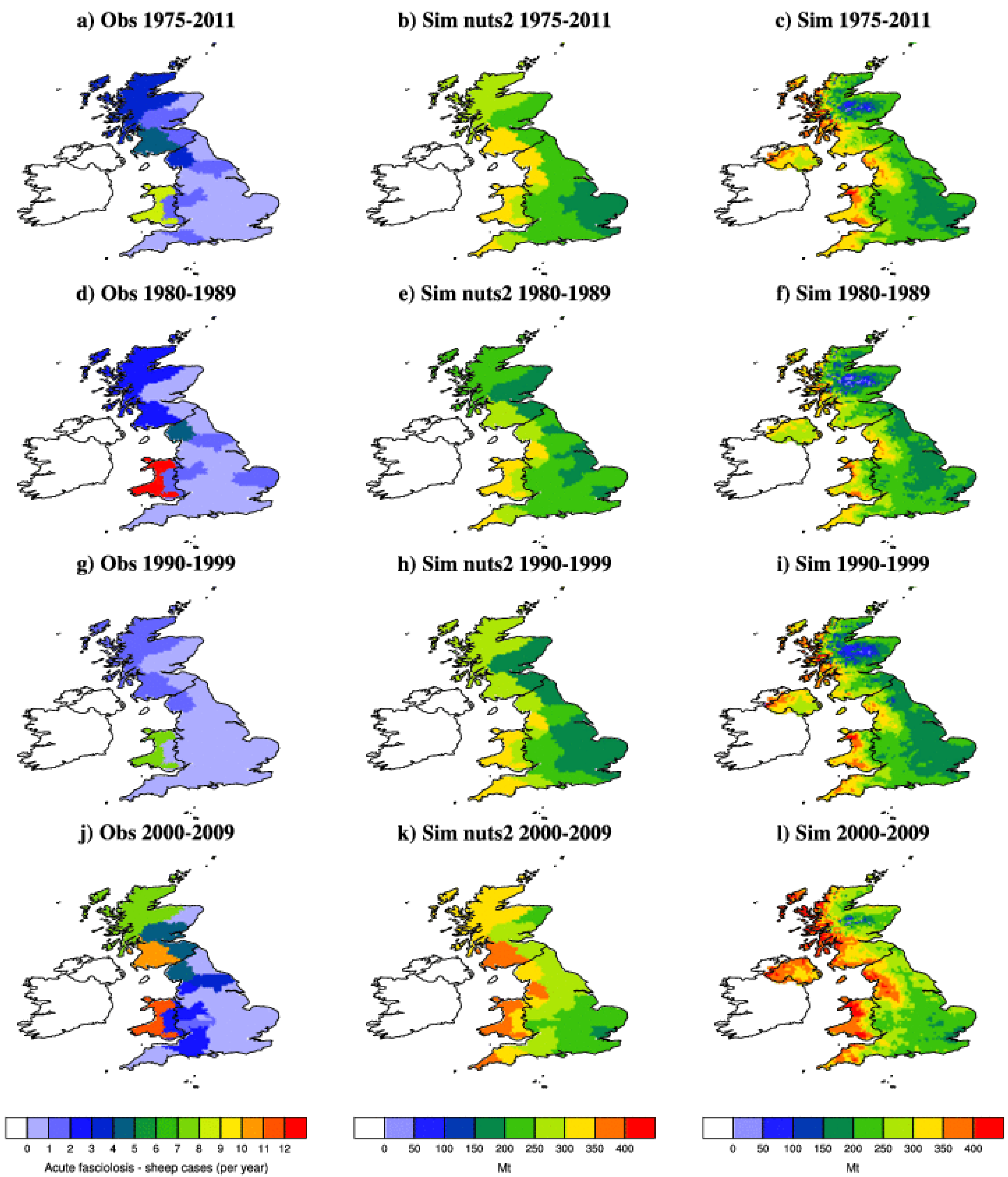
Climate "risk" e.g. Mt (Met Office UK data)

Summer infections (sheep acute) (VLA/SAC data)

Mt in MJJASO compared with sheep acute cases occurring the following winter/spring e.g. ONDJFM (summer infections)

Caminade et al., 2015 after Ollerenshaw & Rollands, 1959

Recent context observation vs model (1/2)



Summer infections Mt model vs acute fasciolosis cases (sheep)

300<Mt<400 occasional losses
400<Mt<474 disease prevalent
475<Mt severe epidemics

Observed acute infections increased during the 2000s over western UK consistently with the climate-driven disease model results

Model fails to reproduce the 1980s hot spot over western Wales

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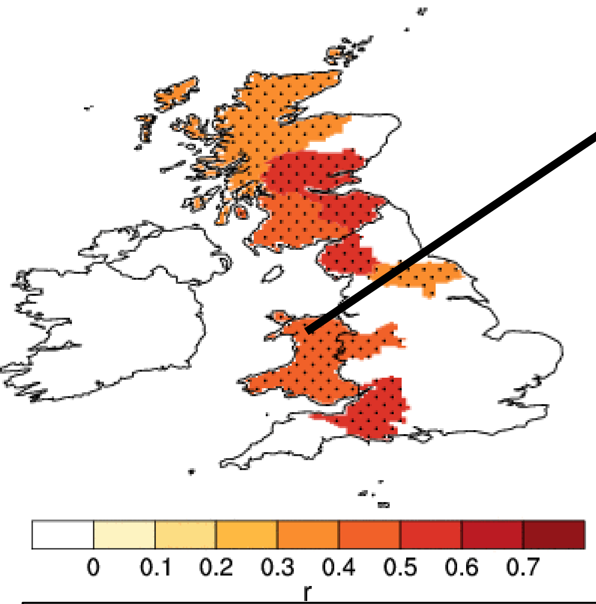
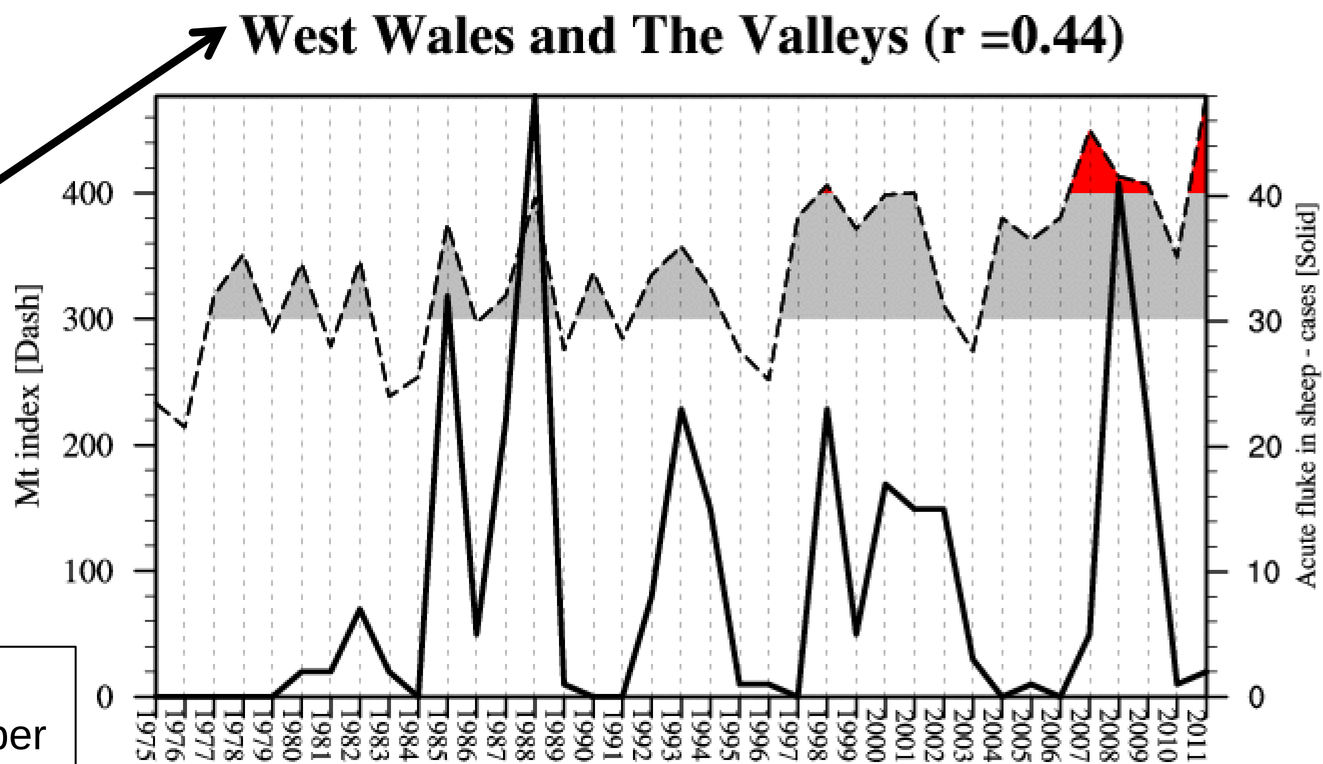
Recent context observation vs model (2/2)





Correlation between
Mt model and observed number of sheep with acute infections (summer infections)
1975-2011
Dotted area:
95% confidence interval (T-test)
Regions with less than one infected sheep/year have been masked

- **Number of sheep with acute fascioliasis (VIDA)**

--- Mt Model values

Gray shading: 300<Mt<400

Red shading: 400<Mt

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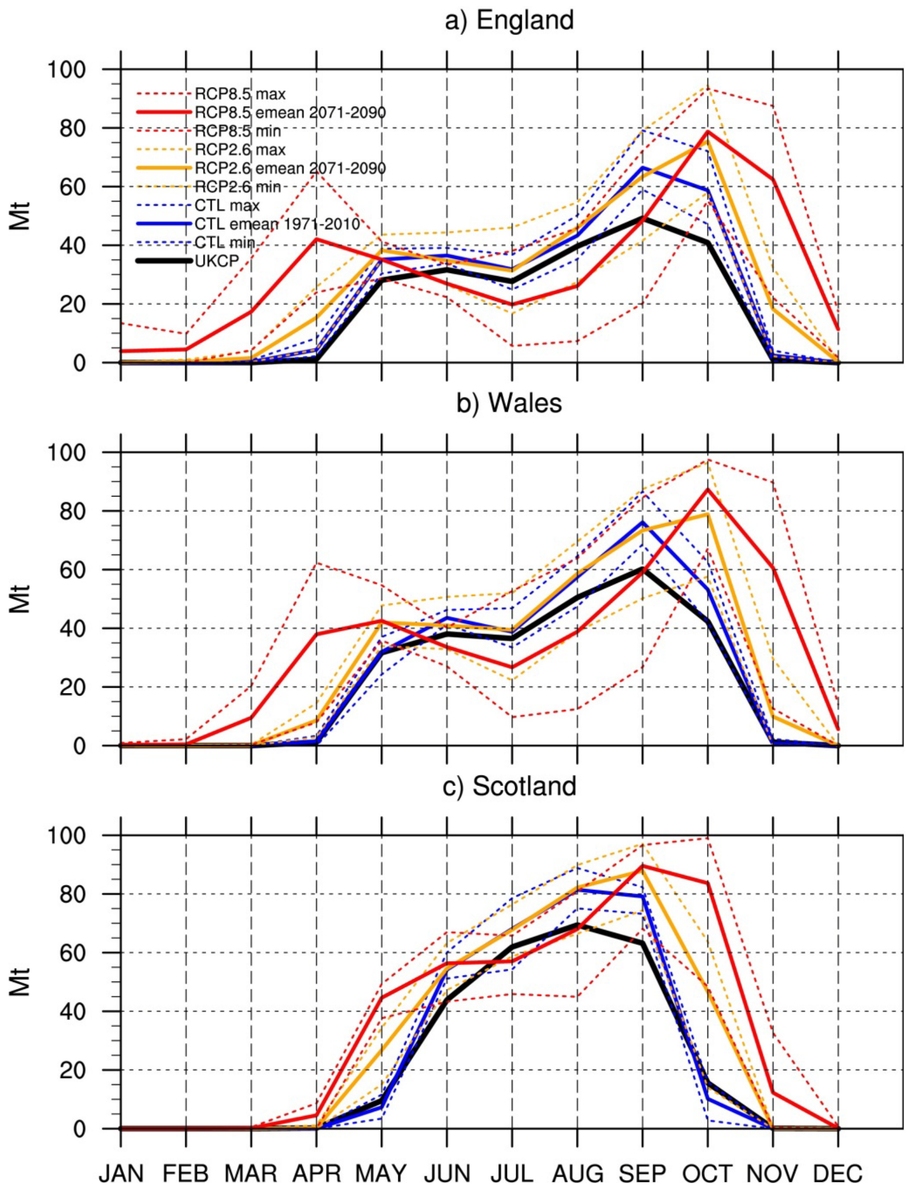
Fasciolosis over the UK future scenarios



Moderate emission scenario-> slight increase in transmission risk in October for the 2080s

Extreme emission scenario-> decreased risk in summer, increased risk in Apr-May and Oct-Nov for England and Wales.

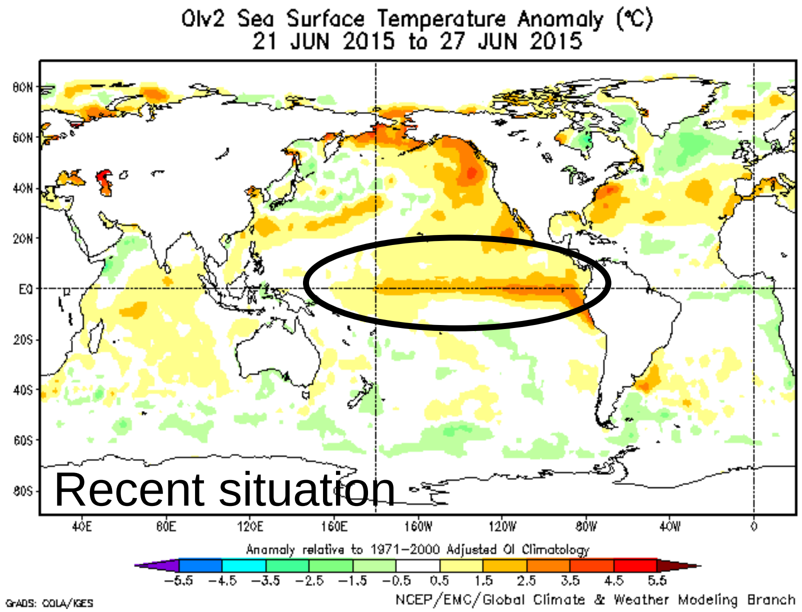
Future risk over Scotland looks like past observations over western Wales, and this is the most endemic region according to the observed VIDA-SAC clinical data

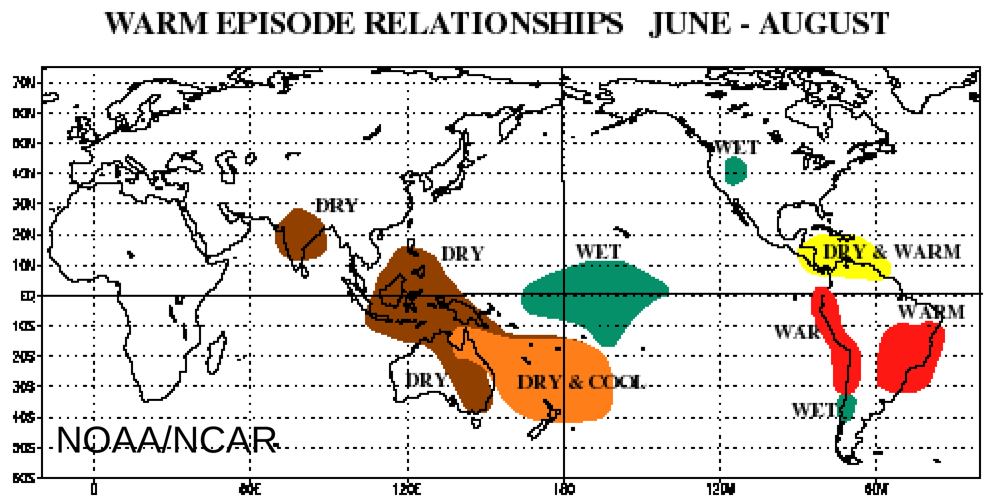
GLOWORM

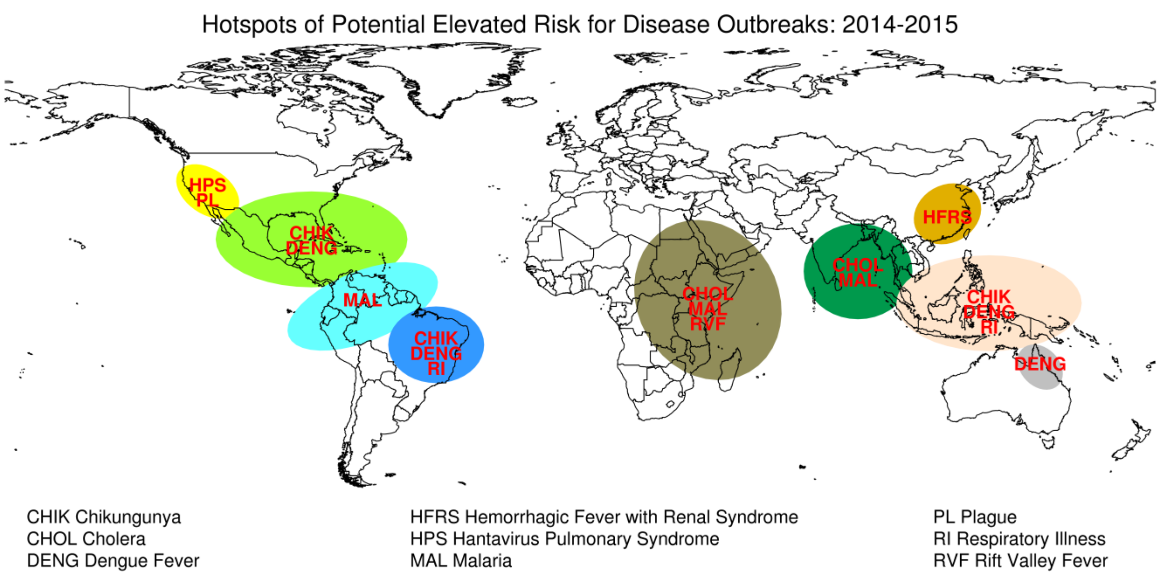
Conclusions and Perspectives

- More recent evidences that climate change favoured the rise of vector-borne diseases to higher latitudes and altitudes **but**: other factors to consider: **increased travel and trade, land use, vulnerability of populations, drug resistance, economic development**…
- Current dynamical disease models can be improved (mosquitoes experience weather instead of climate + need to consider vulnerability data e.g. Healthy Futures EU project)
- **Multi data source simulations useful and needed** (using ensembles of disease models, climate models, population and climate change scenarios, economic projections…) -> Work in progress ND-GAIN (Notre-Dame university, USA), World Bank…
- Stop the race for model skill: look at where things might occur instead to anticipate the risk – potential ecological niche
- Multi-disciplinary projects required (entomologists, epidemiologists, human and animal health specialists, climatologists-meteorologists, human scientists, interface scientists) e.g. **One Health approach**
- Operational risk models (seasonal forecasts or based on satellite data…) for climate sensitive diseases (agro-meteorology far ahead) and link with climate services in their infancy stages. This is work in progress…

Summer 2015: El Niňo is already there…







Chretien et al., 2015

June 2015 – ANSES Paris

Heatwave related deaths:
India, Pakistan (spring)

Chikungunya cases:
south-western USA (Texas)
Colombia, Peru, Mexico, Caribeans

Dengue cases:
South east Asia, Sri Lanka, India

To be continued…

Thanks for your attention

NATURAL
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ISI-MIP

SEVENTH FRAMEWORK PROGRAMME

GLOWORM

http://www.gloworm.eu/

QWeCI

http://www.liv.ac.uk/qweci/

HEALTHY FUTURES

http://www.healthyfutures.eu/

ENHanCE

http://www.liv.ac.uk/infection-and-global-health/research/enhance/