Institut de recherche pour le développement

Heath & Climate change
IRD expertise and researches

Table of contents

I. Introduction

IRD research focus on the health consequences of climate evolution by developing, in collaboration with its partners in the South and a number of French, European and international health institutes, research programs on population health, in relation with climate change.

Historically specialized on tropical infectious and parasitic diseases, and nutritional disorders, the IRD is moving and adapting to better take into consideration the various health consequences of climate evolution on the most vulnerable populations in the South.

As of today, it is still very difficult to measure the impacts of climate on health in developing countries as data is not yet available or is very rare. In addition, we can notice a huge disparity in research on infectious diseases and that on chronic diseases for existing research.

Even though data is lacking, there is no doubt that there will most probably be millions of victims of climate impacts on health. It is thus crucial that improvement of health and well-being be one of the main objectives in development policies. Such a policy will also make it possible to act on the adaptation capacity of people and public entities to adapt to these threats.

In this context, promotion of awareness raising, gathering and provision of reliable scientific data, and the strengthening of health systems form key work activities for IRD and its partners in the health sector. One essential component for the IRD is thus the development or strengthening of scientific communities in developing countries so that they can produce data and stimulate mobilization, innovation and militancy in future debates.

Global information related to climate change and health can be found in the following literature:

- **Moving towards a new discipline - Health ecology (© Pour la Science - INRA 2015)**
- **Changement climatique - Menaces sur notre santé ! (Grand angle Science & santé ● N° 28 ● novembre - décembre 2015)**
- **Health can help saving negotiation on climate change (www.thelancet.com Vol 385 June 13, 2015)**

Section II of this document provides an overview of the research work conducted by the IRD in partnership with developing countries and partner institutions.

Annex I of this document provides more detailed information related to the different publications and studies mentioned in section II.

Annex II of the document provides the list of IRD scientific departments that are involved in work related to health and environment, and some contact persons within these departments, mainly people who have contributed to studies highlighted in section II.

II. IRD's Research Work on Climate Change, Health, and Adaptation

The IRD is involved in a number of key topics related to the linkages between environment changes, climate change and health.

This document intends to give an overview of the main thematic studied within the Institute.

It is to be noted that, most of this work includes the notion of adaptation to climate change, through for instance technology transfer, health system adaptation, the development of early warning system, etc.

Detailed descriptions of the research work and papers highlighted in the different sub-sections of section II are provided in Annex 1 of this document and accessible directly through the link inserted in the titles of the papers.

1. ***Emerging diseases, and changes in the spatial and temporal distribution of infectious and vector-borne diseases***

The linkages between climate, emergence, and spatial and temporal distribution of diseases is still difficult to establish.
Most, if not all, of the research often lacks references for the establishment of past distribution and are potentially biased by confusing factors such as the spreading of diseases by human activities and/or transports.

However, it remains essential to identify and map zones that are the most vulnerable to these new health risks and identify whether intervention measures are necessary for the population.

As changes in climate form continuous processes and are, by definition, complex with extremely heterogeneous consequences, a key component is to adapt the gathering of scientific data both in time (avoiding one-off examination of obvious short-term features such as those occurring during extreme climatic events), and in space as, in one region, places lacking the necessary health infrastructure will be those the most affected.

Among the research and publications including contributions from the IRD, we can list (Further information regarding each of the documents listed below is accessible from the direct link inserted on the titles below, that bring to Annex I of this document):

- Autochthonous Chikungunya Transmission and Extreme Climate Events in Southern France (Received: March 2, 2015, Accepted: May 27, 2015, Published: June 16, 2015, Copyright: © 2015 Roiz et al.)
- Links between Climate, Malaria, and Wetlands in the Amazon Basin (Emerging Infectious Diseases • www.cdc.gov/eid • Vol. 15, No. 4, April 2009)
- Water and public health in Sahelian countries: The case of infectious disease in Saint-Louis (Senegal) (Sécheresse vol. 20, n° 1, janvier-février-mars 2009)
- Regional-scale climate-variability synchrony of cholera epidemics in West Africa (BMC Infectious Diseases 2007, 7:20 doi:10.1186/1471-2334-7-20, © 2007 Constantin de Magny et al; licensee BioMed Central Ltd.)
- Seasonal Dynamics of Phlebotomine Sand Fly Species Proven Vectors of Mediterranean Leishmaniasis Caused by Leishmania infantum (PLOS Neglected Tropical Diseases | DOI:10.1371/journal.pntd.0004458 February 22, 2016, Copyright: © 2016 Alten et al.)
- Emerging infectious diseases: state of the art and perspectives (ISBN: 978 -2 -11- 008586 -3)
- Spatio-temporal Patterns and Landscape-Associated Risk of Buruli Ulcer in Akonolinga, Cameroon (Landier J, Gaudart J, Carolan K, Lo Seen D, Gue´gan J-F, et al. (2014) Spatio-temporal Patterns and Landscape-Associated Risk of Buruli Ulcer in Akonolinga, Cameroon. PLoS Negl Trop Dis 8(9): e3123. doi:10.1371/journal.pntd.0003123)

2. ***Development of early warning systems***

A second set of research is linked to the correlation of time series of cases of several diseases with time series of meteorological parameters.
This type of research makes it possible to specify the effects of medium and long-term climate changes on the appearance of epidemics of infectious diseases and the increase in their frequency.

More generally, this work allows the development of statistical models to explain and predict epidemics of various infectious diseases, prefiguring development of early warning systems.

Among the research and publications including contributions from the IRD, we can list (Further information regarding each of the documents listed below is accessible from the direct link inserted on the titles below, that bring to Annex I of this document):

- Combining Hydrology and Mosquito Population Models to Identify the Drivers of Rift Valley Fever Emergence in Semi-Arid Regions of West Africa (Received March 16, 2012; Accepted July 7, 2012; Published August 21, 2012)
- Land cover, land use and malaria in the Amazon: a systematic literature review of studies using remotely sensed data (Stefani et al. Malaria Journal 2013, 12:192, http://www.malariajournal.com/content/12/1/192, © 2013 Stefani et al.; licensee BioMed Central Ltd.)
- Complex temporal climate signals drive the emergence of human water-borne disease (Emerging Microbes and Infections (2014) 3, e56; doi:10.1038/emi.2014.56_ 2014 SSCC. All rights reserved 2222-1751/14)
- Predicting Dengue Fever Outbreaks in French Guiana Using Climate Indicators (PLOS Neglected Tropical Diseases | DOI:10.1371/journal.pntd.0004681 April 29, 2016, Copyright: © 2016 Adde et al.)
- Climate drives the meningitis epidemics onset in West Africa

3. Health prospects in the South

While weather conditions have a considerable effect on disease spread in water and those spread by arthropods and even by reservoir animals, effects of climate change is not always propitious for the spread of vector diseases.
It is very probable that an increase in temperatures and greater variability of precipitations will result in very variable health pictures in tropical regions.

Another source of uncertainty relates to the specific responsibility of climate in relation to the other parameters, especially in countries in the South where anthropisation takes many forms and affects all socio-ecosystems, and where biophysical and human aspects are closely entwined (cf. industry, agriculture, urbanization, transport, etc.). The impact of these other pressures on the environment is to be combined with that of climate change.

Ecological transition with serious repercussions for public health will therefore be added to the epidemiological transition experienced by developing regions.

Among the research and publications including contributions from the IRD, we can list (Further information regarding each of the documents listed below is accessible from the direct link inserted on the titles below, that bring to Annex I of this document):

- Global Impact of Mosquito Biodiversity, Human Vector-Borne Diseases and Environmental Change (The Importance of Biological Interactions in the Study of Biodiversity, Edited by Dr. Jordi Lapez-Pujol, ISBN 978-953-307-751-2, Hard cover, 390 pages, Publisher InTech, Published online 22, September, 2011, Published in print edition September, 2011)
- Changement climatique et santé : en a-t-on trop dit ou pas assez ? (2015)
- Estimating heat stress from climate-based indicators: present-day biases and future spreads in the CMIP5 global climate model ensemble (Environ. Res. Lett. 10 (2015) 084013 doi:10.1088/1748-9326/10/8/084013)

- Club Climat Agriculture ; DEUXIEME PARTIE : ADAPTATION ; Les nouveautés de la recherche scientifique : Changement climatique et écologie de la santé (Dossier d'actualité n°6, Spécial COP21, 17 novembre 2015)
- Spatio-temporal variability of NDVI–precipitation over southernmost South America: possible linkages between climate signals and epidemics (Environ. Res. Lett. 3 (2008) 044008 (9pp) doi:10.1088/1748-9326/3/4/044008)

In addition, the IRD is leading the RELAIS *(Regional Epidemiological Landscape Amazon Information System)* Project, in partnership with institutions in Brazil, to study the epidemic risks in Latin America and linkages between environment and human health.

4. Anticipating crises by adapting health systems

The improvement of health and care systems obviously includes the implementation of surveillance and health monitoring systems. This constitutes the first adaptation measure to climate change.

Quality of ecosystems, air, food and potable water, and better education and information for the public on these topics will enhance the compliance of the population and generate reactiveness in the face of climate threats. This set of actions refers to a new subject known as health ecology.

Long-term investments aimed at limiting global warning can sometimes seem discouraging as no concrete results can be seen. Those made in the health sector will have concrete and quantifiable results and benefits for the greatest number.

Among the research and publications including contributions from the IRD, we can refer to the publication entitled Socio-economic and Climate Factors Associated with Dengue Fever Spatial Heterogeneity: A Worked Example in New Caledonia (PLOS Neglected Tropical Diseases | DOI:10.1371/journal.pntd.0004211 December 1, 2015, Copyright: © 2015 Teurlai et al.).

5. The specific linkages between climate change, water and health

A key topic largely studied in relation to climate change is the link between climate change, access to water and health potential impacts.
Among the research and publications including contributions from the IRD, we can list (Further information regarding each of the documents listed below is accessible from the direct link inserted on the titles below, that bring to Annex I of this document):

- Options for water storage and rainwater harvesting to improve health and resilience against climate change in Africa (Received: 21 December 2010 / Accepted: 29 January 2012 /Published online: 25 February 2012, Springer-Verlag 2012)
- Climate, water, and health in the West African Sahel (Sécheresse n° 3, vol. 15, septembre 2004)
- Health Impacts of Small Reservoirs in Burkina Faso (IWMI Working Paper 136, ISSN 2012-5763, ISBN 978-92-9090-717-6, Copyright © 2009, by IWMI)
- Seasonal forecasting for Africa: Water, health management and capacity building (ISBN 978-0-9568561-3-5, © 2012 Tudor Rose. All rights reserved)
- Changements environnementaux et maladies infectieuses : mieux coordonner la surveillance (adsp n° 93 décembre 2015)

III. Conclusion remarks by Jean-François Guégan (Directeur de recherche, Maladies infectieuses et vecteurs : écologie, génétique, évolution et contrôle)

Information on recent work in the area of **climate impacts on human health**, including changes in the geographical distribution of diseases; new and emerging health issues, including tropical diseases and their impacts on social and economic structures, as well as the issues of malnutrition, waterborne diseases, vector-borne diseases and disaster impacts; and the effects of climate change on health and productivity in the workplace, with implications for occupational health, safety and social protection

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1 - Very few research studies on the long term are available, especially in countries of the South. Temporal series, which better capture long-term climatic patterns and their associations with diseases (better than spatial mapping for which many other drivers, notably human activities-mediated, may also explain observations), are needed. There is a need to develop long-term ecological research surveys and networking, adopting a regional scale perspective. The Mediterranean area is a climate change-health research desert for instance.

2 - Long-term series and population dynamics studies of human disease cases, and/or their vector or reservoir hosts clearly show that extreme events (floods, temperature,…) may strongly impact health outcomes. Vector-borne and water-borne diseases outbreaks may be influenced by such extreme events. Understanding of extreme event impacts needs to be embedded into a long-term approach, not only focusing on short-term outcomes.

3 – It is important to select evidenced-based case-studies that clearly show the interactions between climate change and health, in order to make benefit from these experiences to develop further studies. The scientific question is central and needs to be asked before the development and design of research work (see comment 4).

4 - Most of actual research on climate change and health are not designed to address the question raised. Climate change is seen as a pretext, and a confusion is still persisting between meteorological conditions and health, and climate change and health in a large part of the scientific literature.

5 – There is a need for a scientific, institutional authority (or a "landmark") on the topic since most of the literature is composed of review or synthesis' papers. Case-studies are dramatically lacking. Specifically on the sub-topic of climate change-migration-and-health, very few (17 on near 1800) are really dealing with this subject.

6 – There is a need for developing trainings in the field of spatial and temporal statistics as it is clearly lacking, and deciding on referenced training laboratories and institutes on the topic of climate change and health.

7 - Cascade-of-effects phenomena are not well understood, from global to local and back (spatial organization and hierarchical levels). Training in such complex systems is also a priority.

8 - Since most of existing studies deal with the impacts of climate change on health, retroaction and feedbacks from health to climate adaptation and mitigation need to be studied and understood.

9 - Neglected endemic tropical diseases – most are indirectly transmitted diseases with a vector or a reservoir sensitive to climatic conditions - even those with low incidence and prevalence may contribute to poverty. Diagonalization of research and medical studies need to be developed associating research on neglected diseases with those on HIV, malaria and tuberculosis.

10 - Climate change, sustainable agriculture and health. Promoting crop, plant and animal local genetic resources and diversity that may benefit to both local/national economy, better adaptation

to climate change and human nutrition (rice varieties, cattle races,…), and that will not suffer from (new) natural enemies (virus, bacteria, pests,…) adapted to these new conditions.

11 -Train and communicate to the public, to the children, to the youngest the consequences of climate change on health, nutrition and well-being, and insist on retroaction measures and feedbacks that may permit better adaptation and mitigation.

12 - Develop scenarios that take into account climate change, agriculture development and options, socio-economy and health put together.

Annex 1: List and detailed descriptions of research work and publications highlighted in section II

1. ***Options for water storage and rainwater harvesting to improve health and resilience against climate change in Africa*** ***(Received: 21 December 2010 / Accepted: 29 January 2012 /Published online: 25 February 2012, Springer-Verlag 2012)***

Authors:
Eline Boelee, Mekonnen Yohannes, Jean-Noel Poda, Matthew McCartney, **Philippe Cecchi (IRD)**, Solomon Kibret, Fitsum Hagos, Hammou Laamrani

Conclusions:
Our findings confirm that water storage, widely promoted for climate change adaptation, can indeed increase health risks, and it is vital that consideration is given to how these adverse impacts can be mitigated. Currently, too little thought is given to the possible public health implications of different options for rainwater harvesting and water storage. In the rush to develop water harvesting and storage for climate change adaptation, care must be taken not to increase the health burden of already vulnerable people. Poorly planned and managed water storage will have adverse implications for public health, which can undermine the sustainability of the interventions. If adverse impacts are to be avoided in future, much greater consideration must be given to the full range of potential health impacts and possible mitigation measures under the altered conditions that will result from climate change.

It is very hard to quantify the impact of climate variability and climate change on disease transmission because of the myriad influences of human factors and other uncertainties. However, it is clear that some adaptation measures, such as increased rainwater harvesting and water storage, may expand the open water surface in susceptible areas with vulnerable populations and lead to increased transmission of water-related diseases. By considering a wider range of options in planning, design, and management of water storage, several health risks could be minimized. PHIA, even if only partially applied, can help to further address these risks in a sustainable way, especially for community-managed water storage. The approach can be further developed to better incorporate climate change issues.

2. ***Autochthonous Chikungunya Transmission and Extreme Climate Events in Southern France*** ***(Received: March 2, 2015, Accepted: May 27, 2015, Published: June 16, 2015, Copyright: © 2015 Roiz et al.)***

Authors:
David Roiz, Philippe Boussès, Frédéric Simard, Christophe Paupy, Didier Fontenille (all from IRD)

Author Summary:
During last years, we have seen an astonishing expansion of Chikungunya virus and an increase in dengue cases worldwide, together with the worldwide expansion of the Asian tiger mosquito *Aedes albopictus*. In addition, extreme rainfall events are envisaged to become increasingly likely as a result of ongoing climate change, but controversy surrounds the relationship between extreme rainfall events and mosquito-borne diseases. The common view in most works on climate and mosquito-borne diseases is that heavy rainfalls produce a flushing effect of immature mosquitoes in breeding

containers, diminishing the mosquito abundance and in turn diminishing disease transmission. We analysed the relationships between the autochthonous chikungunya transmission in Montpellier (Southern France) in 2014, an extreme rainfall event that flooded the city, and a close monitoring of the vector *Ae*. *albopictus*, revealing an unexpected pattern. This extreme rainfall event did not, in fact, decrease but instead had increased the global risk of chikungunya transmission by sustaining high abundance of the disease vector *Ae*. *albopictus*, hence extending the transmission period. We propose that an effort on source reduction campaigns must be implemented after heavy rainfall events. These results are relevant to those involved in the surveillance and control of chikungunya and dengue transmission in temperate as well as tropical areas.

3. Climate, water, and health in the West African Sahel (Sécheresse n° 3, vol. 15, septembre 2004)

Authors:
Jean-Pierre Besancenot, **Pascal Handschumacher (IRD)**, Jacques-André Ndione, Ibrahima Mbaye, Karine Laaidi

Summary:
From the mouth of the Senegal River to the shores of Lake Chad through to the Sudanese Djezireh, the Sahel stands as an ecological transition (wooded steppe, between the Saharan desert and the Sudanian savannah) and a crossroads of civilisations (where nomadic shepherds and Black settled farmers are converging, the latter gradually taking over from the former towards the South). In this "area between two worlds" people's health is strongly dependent on the natural environment, possibly altered by human action. Simultaneously or in turn, it has something of the nature of both surrounding environments. But the great drought of the 1970s and 1980s deeply altered the health situation, both by its direct effects (*resulting in an increased dry area pathology*) and by the installations it brought about (and those tended to induce the emergence or re-emergence of diseases which were until then characteristic of more humid areas).

Key words: Health, Climate, Water, Sahel

4. Links between Climate, Malaria, and Wetlands in the Amazon Basin (Emerging Infectious Diseases • www.cdc.gov/eid • Vol. 15, No. 4, April 2009)

Authors:
Sarah H. Olson, Ronald Gangnon, **Eric Elguero (IRD), Laurent Durieux (IRD), Jean-François Guégan (IRD),** Jonathan A. Foley, and Jonathan A. Patz

Summary:
Climate changes are altering patterns of temperature and precipitation, potentially affecting regions of malaria transmission. We show that areas of the Amazon Basin with few wetlands show a variable relationship between precipitation and malaria, while areas with extensive wetlands show a negative relationship with malaria incidence.

5. Water and public health in Sahelian countries: The case of infectious disease in Saint-Louis (Senegal) (Sécheresse vol. 20, n° 1, janvier-février-mars 2009)

Authors:
Moussa Mbaye, **Gil Mahé (IRD)**, **Eric Servat (IRD)**, Richard Laganier, Sylvain Bigot, Oumar Diop, **Jean-Francois Guégan (IRD)**

Abstract:
Rainfall occurrence in the Sahelian region in places like Saint-Louis (Senegal) depends essentially on Africa's monsoon flux from the South Atlantic drift. This monsoon plays an important role while provoking hydrological consequences that result from climate variability over time and space. Such consequences may be droughts or floods with harsh consequences for the socioeconomic activities of the urban population and the environment. For example, the Sahelian drought of the 1970s forced the urban populations to relocate to former backwaters, ponds and mud flats located within Saint-Louis (Senegal). However, better levels of rainfall in the late 1990s subjected the urban population to severe flooding and precarious environmental conditions. This situation is due to the poor and inadequate water network systems which in most cases are old and obsolete. Hence, the poor environmental conditions and stagnant water encourage the breeding of several species of mosquitoe. Among the species, Anopheles and Aedes are the most dangerous because of the transmission of malaria and yellow fever. It is thus important to investigate and model the population's vulnerability to infectious diseases as a result of current climate variation and its consequences. This work entails the integration of spatial and non-spatial data within the technological framework of a Geographical Information System (GIS), in order to assess the health impacts due to climatic fluctuation. The results show that there is a relationship between periods of flooding, cases of disease and mosquitoes.

Key words: human health, mosquitoes, Sahel, Senegal, water resources.

6. *Health Impacts of Small Reservoirs in Burkina Faso (IWMI Working Paper 136, ISSN 2012-5763, ISBN 978-92-9090-717-6, Copyright © 2009, by IWMI)*

Authors:
Eline Boelee, **Philippe Cecchi (IRD)** and André Koné

Summary
In this paper we discuss health impacts of small reservoirs in Burkina Faso. Small earth reservoirs have been increasingly promoted in several West African countries since the 1980s but the environmental and health impacts resulting from this type of intervention remain poorly documented.
However, some secondary information turned out to be available in "gray" literature such as students' theses. Data from different sources were combined into national maps and synthesized for small reservoirs in different climatic zones.
In Burkina Faso, around 1,700 small dams were constructed, most of them during the last 30 years, to provide water to people and livestock in drought-prone areas. In the drier parts of the country, these reservoirs are still mainly used for watering livestock. In other areas, the water is increasingly used for irrigation of vegetables. Almost everywhere these man-made lakes appear as multiple use systems. A new government strategy initiated in 2002 foresees the construction of more dams and 20,000 ha of new village irrigation systems. In many places, the creation of small reservoirs in Burkina Faso has resulted in increased household income through productive agricultural activities upstream and downstream of the reservoir. However, in almost all cases no preventive measures have been taken to ensure that the small reservoirs do not have adverse environmental and health impacts.
The water-related diseases most directly linked to the construction of small reservoirs are schistosomiasis and malaria, though emerging pathogens such as cyanobacteria are expected to present major health risks in the near future. For schistosomiasis, some field studies found increased transmission after construction of the reservoirs, especially in the semiarid north, where the reservoirs provided perennial water bodies in an area where previously the intermediate snail host depended on temporary pools. Human behavior regarding water use and hygiene however is more important than the presence of snails as a determinant of transmission. For malaria, the link is even

more complicated as mosquitoes hardly breed in the reservoir itself and an increase in vector mosquitoes does not necessarily lead to increased malaria prevalence.
Knowledge of water-related diseases, including causes and avoidance measures, remains low in Burkina Faso. Public awareness campaigns are necessary to explain to communities the possible impacts of reservoirs and irrigated agriculture on their health. This should be done even before the promotion of preventive and curative measures against the water-related diseases. Alternative water sources for domestic supply should be developed if possible. The reduction of the negative impacts of small reservoirs on the environment and public health requires an integrated approach, which specifically identifies the enhancing and limiting factors that influence environmental impacts and the transmission of diseases in the reservoir environment. It is only from a good knowledge of the risks that effective environmental management and disease control programs can be developed in a way that fits with regional strategies for poverty alleviation and sustainable development.

7. *Global Impact of Mosquito Biodiversity, Human Vector-Borne Diseases and Environmental Change (The Importance of Biological Interactions in the Study of Biodiversity, Edited by Dr. Jordi Lapez-Pujol, ISBN 978-953-307-751-2, Hard cover, 390 pages, Publisher InTech, Published online 22, September, 2011, Published in print edition September, 2011)*

Authors:
Sylvie Manguin (IRD) and **Christophe Boëte (IRD)**

Conclusions:
Aedes aegypti and *Ae. albopictus* are forest mosquitoes. In their original habitat they breed in tree-holes, rock holes, fruit husks and other small collections of water. In the peridomestic environment they exploit man-made articles that substitute for these breeding sites. In the modern urban environment the abundance of such articles is the key factor in the abundance of these species and of the burgeoning problem of dengue, chikungunya and other viral infections that they transmit. Modern transportation technology has encouraged widespread commerce in items that can be infested; classic examples are used tires, live plants, and exotic fishes. Accelerating global trade in such items will increase the probability of introduction of such species into new regions. The advent of tens of millions of tightly packed, locked shipping containers (Fig. 8), the onus on speed in their handling and transportation, and above all their delivery unopened to their ultimate destination, have made conventional inspection in harbour redundant (Reiter, 2010a). In addition, the exponential increase in cheap air travel and transport has facilitated the movement of human and animal pathogens. In the past three decades, this mobility has sparked outbreaks of diseases such as dengue and chikungunya in many places around the world.
Recent events include epidemics of chikungunya in La Reunion Island and northern Italy and of dengue in the Cape Verde Islands. Spectacular examples of other exotic pathogens, such as the explosive panzootic of West Nile virus in the New World are here to remind us the vital importance of a better knowledge and good understanding of the fine interactions between pathogens, mosquitoes and environmental changes, and the need to clearly admit and evaluate our role and responsibility in those phenomenons.

8. *Combining Hydrology and Mosquito Population Models to Identify the Drivers of Rift Valley Fever Emergence in Semi-Arid Regions of West Africa (Received March 16, 2012; Accepted July 7, 2012; Published August 21, 2012)*

Authors:
Valérie Soti, Annelise Tran, Pascal Degenne, Véronique Chevalier, Danny Lo Seen, Yaya Thiongane, Mawlouth Diallo, **Jean-François Guégan (IRD), Didier Fontenille (IRD)**

Abstract:

Background:
Rift Valley fever (RVF) is a vector-borne viral zoonosis of increasing global importance. RVF virus (RVFV) is transmitted either through exposure to infected animals or through bites from different species of infected mosquitoes, mainly of Aedes and Culex genera. These mosquitoes are very sensitive to environmental conditions, which may determine their presence, biology, and abundance. In East Africa, RVF outbreaks are known to be closely associated with heavy rainfall events, unlike in the semi-arid regions of West Africa where the drivers of RVF emergence remain poorly understood. The assumed importance of temporary ponds and rainfall temporal distribution therefore needs to be investigated.
Methodology/Principal Findings: A hydrological model is combined with a mosquito population model to predict the abundance of the two main mosquito species (Aedes vexans and Culex poicilipes) involved in RVFV transmission in Senegal.
The study area is an agropastoral zone located in the Ferlo Valley, characterized by a dense network of temporary water ponds which constitute mosquito breeding sites. The hydrological model uses daily rainfall as input to simulate variations of pond surface areas. The mosquito population model is mechanistic, considers both aquatic and adult stages and is driven by pond dynamics. Once validated using hydrological and entomological field data, the model was used to simulate the abundance dynamics of the two mosquito species over a 43-year period (1961–2003). We analysed the predicted dynamics of mosquito populations with regards to the years of main outbreaks. The results showed that the main RVF outbreaks occurred during years with simultaneous high abundances of both species.

Conclusion/Significance:
Our study provides for the first time a mechanistic insight on RVFV transmission in West Africa. It highlights the complementary roles of Aedes vexans and Culex poicilipes mosquitoes in virus transmission, and recommends the identification of rainfall patterns favourable for RVFV amplification.

9. Seasonal forecasting for Africa: Water, health management and capacity building (ISBN 978-0-9568561-3-5, © 2012 Tudor Rose. All rights reserved)

Authors:
Philippe Dandin, Jean-Pierre Céron, Isabelle Charon, Jean-Michel Soubeyroux, Yves M. Tourre, Christian Viel, François Vinit , Metéo-France, Direction de la Climatologie; **Jean-Claude Bader, Institut de Recherche pour le Développement (IRD)**; Michel Déqué, Flore Mounier, Jean-Philippe Piedelièvre, Météo-France and CNRS, Centre National de Recherches Météorologiques; Laurent Labbé, Centre Africain pour les Applications de la Météorologie au Développement (ACMAD); Cécile Vignolles, Centre National d'Etudes Spatiales (CNES)

Lessons learned:
Seasonal forecasting recalls for the need for - and benefit of – long term observation and series.
The Manaruali hydrological or vector-borne disease applications show that valuable climate information can be delivered today, taking advantage of the state-of- the-art products and knowledge available in the WMO GfCS framework. While direct application of seasonal forecasting into decision-making processes is not that simple, and there is a need for research efforts on subjects which are as yet poorly known, some examples already pave the way for further work and lessons can be learned from these. Clearly, the availability of long series of observation, both for climate data and impact data, is a determining factor. In previous centuries, various organizations have aimed at developing the economic use of the Senegal River waters, and for that purpose made observations. Long records are therefore available today, and of the utmost importance for setting up a climate

service that can tackle a high variability and grasp so me past occurrences of extreme events. And it stands to reason that monitoring the terrestrial system today is a key to understanding, predicting and optimizing activities in the future. Hydrologists from the French Research for Development Institute and climatologists from Meteo France have worked together to build a predictive system base d on seasonal forecasting. It was proven that seasonal forecasting could capture the yearly variability of precipitation, enabling flow and extreme events - being generated by extremely dry or wet years - to be reasonably well predicted. Meteorologists alone would never have achieved success in efficiently work on the Senegal River's flow regimes. They needed to join forces with hydro logy scientists.
Similarly, without the user being at the core of the decision-making process, and without the strategy for the development of the Senegal River basin being structured as an international organization, having a perfect knowledge of all the requirements for the various uses of water in the area, knowing the ins and outs of the dam management and all other hidden agendas, the information would have been void. Science is difficult enough: all stakeholders have to join forces to make climate in form at ion alive and fruitful!

10. ***Land cover, land use and malaria in the Amazon: a systematic literature review of studies using remotely sensed data*** ***(Stefani et al. Malaria Journal 2013, 12:192, http://www.malariajournal.com/content/12/1/192, © 2013 Stefani et al.; licensee BioMed Central Ltd.)***

Authors:
Aurélia Stefani, Isabelle Dusfour, Ana Paula SA Corrêa, Manoel CB Cruz, Nadine Dessay, Allan KR Galardo, Clícia D Galardo, Romain Girod, Margarete SM Gomes, Helen Gurgel, Ana Cristina F Lima, Eduardo S Moreno, Lise Musset, Mathieu Nacher, Alana CS Soares, Bernard Carme, and **Emmanuel Roux (IRD)**

Abstract:
The nine countries sharing the Amazon forest accounted for 89% of all malaria cases reported in the Americas in 2008.
Remote sensing can help identify the environmental determinants of malaria transmission and their temporo-spatial evolution. Seventeen studies characterizing land cover or land use features, and relating them to malaria in the Amazon subregion, were identified. These were reviewed in order to improve the understanding of the land cover/use class roles in malaria transmission. The indicators affecting the transmission risk were summarized in terms of temporal components, landscape fragmentation and anthropic pressure. This review helps to define a framework for future studies aiming to characterize and monitor malaria.

11. ***Complex temporal climate signals drive the emergence of human water-borne disease (Emerging Microbes and Infections (2014) 3, e56; doi:10.1038/emi.2014.56_ 2014 SSCC. All rights reserved 2222-1751/14)***

Authors:
Aaron Morris, **Rodolphe E Gozlan (IRD),** Hossein Hassani, Demetra Andreou, Pierre Couppié and **Jean-François Guégan (IRD)**

Summary:
Predominantly occurring in developing parts of the world, Buruli ulcer is a severely disabling mycobacterium infection which often leads to extensive necrosis of the skin. While the exact route of transmission remains uncertain, like many tropical diseases, associations with climate have been previously observed and could help identify the causative agent's ecological niche. In this paper, links between changes in rainfall and outbreaks of Buruli ulcer in French Guiana, an ultraperipheral European territory in the northeast of South America, were identified using a combination of

statistical tests based on singular spectrum analysis, empirical mode decomposition and cross-wavelet coherence analysis. From this, it was possible to postulate for the first time that outbreaks of Buruli ulcer can be triggered by combinations of rainfall patterns occurring on a long (i.e., several years) and short (i.e., seasonal) temporal scale, in addition to stochastic events driven by the El Niño-Southern Oscillation that may disrupt or interact with these patterns.
Long-term forecasting of rainfall trends further suggests the possibility of an upcoming outbreak of Buruli ulcer in French Guiana.

Emerging Microbes and Infections (2014) 3, e56; doi:10.1038/emi.2014.56; published online 6 August 2014

Keywords: climate; coherence analysis; El Niño/La Niña; Mycobacterium ulcerans; rainfall; singular spectrum analysis; Southern America

12. Moving towards a new discipline - Health ecology (© Pour la Science - INRA 2015)

Authors:
Olivier Plantard
Member of the Steering Committee of AAFCC metaprogram. Research Director – INRA-ONIRIS – Biology, Epidemiology and Risk Analysis in Animal Health Joint Research Unit.

Jean-François Guégan
Research Director – CNRS-IRD – Genetics and Evolution of Infectious Diseases Joint Research Unit.

Laurent Huber
Research Director – INRA-AgroParisTech – Environment and Arable
Crops Joint Research Unit

Introduction:
Health is subject to a variety of hazards, especially climatic ones. The future management of health requires urgently the development of models that incorporate climatic variables and the characteristics of ecosystems where diseases develop...without forgetting the human aspect!

13. Changement climatique et santé : en a-t-on trop dit ou pas assez ? (2015)

Jean-Francois Guégan (IRD)
Institut de recherche pour le développement (IRD), UMR Maladies infectieuses et vecteurs, écologie, génétique, évolution et contrôle (MiVEGEC), co-responsable du rapport *Les effets qualitatifs du changement climatique sur la santé en France* (2008)

Conclusion:
Il est nécessaire de revoir l'inférence causale liant changement climatique et maladies infectieuses en enquêtant précisément sur leurs liens directs et indirects dans le cadre de systèmes complexes, en se confrontant aux phénomènes multicausaux et à la relation entre facteurs proximaux et distaux. Si la causalité climatique est nette pour les agents pathogènes marins libres, le rôle du changement climatique reste difficile à démontrer pour les agents transmis indirectement par des vecteurs et/ou des animaux réservoirs. La complexité des situations réelles implique la nécessite d'une compréhension comparative et, au long terme, s'appuyant sur des études multi-sites. Il faut, enfin, développer la physiologie des interactions, car la physiologie des systèmes infectieux ne se résume pas à la somme de celles de ses éléments (agent, vecteur, environnement, physiologie et populations humaines ou animales).

14. ***Changement climatique - Menaces sur notre santé ! (Grand angle Science & santé ● N° 28 ● novembre - décembre 2015)***

Summary:

Asthme, allergies, coups de chaleur, infections, cancers de la peau, accidents... le changement climatique ne s'attaque pas seulement à la biodiversité mais aussi à notre santé.
Longtemps ignorées, les preuves des effets néfastes du réchauffement de la planète sur notre organisme s'accumulent de manière alarmante. À l'occasion de la 21e conférence des Nations unies sur les changements climatiques, la COP21, à Paris du 30 novembre au 11 décembre 2015, dont l'objectif est de limiter le réchauffement en deçà de 2° C à l'horizon 2100, *Science&Santé* revient en détail sur cet enjeu sanitaire majeur du XXIe siècle qui pourrait sauver les négociations sur le climat.

15. ***Estimating heat stress from climate-based indicators: present-day biases and future spreads in the CMIP5 global climate model ensemble (Environ. Res. Lett. 10 (2015) 084013 doi:10.1088/1748-9326/10/8/084013)***

Authors:

Y Zhao, A Ducharne, **B Sultan (IRD)**, P Braconnot and R Vautard

Abstract:

The increased exposure of human populations to heat stress is one of the likely consequences of global warming, and it has detrimental effects on health and labor capacity. Here, we consider the evolution of heat stress under climate change using 21 general circulation models (GCMs). Three heat stress indicators, based on both temperature and humidity conditions, are used to investigate present-day model biases and spreads in future climate projections. Present day estimates of heat stress indicators from observational data shows that humid tropical areas tend to experience more frequent heat stress than other regions do, with a total frequency of heat stress 250–300 d yr−1. The most severe heat stress is found in the Sahel and south India. Present-day GCM simulations tend to underestimate heat stress over the tropics due to dry and cold model biases. The model based estimates are in better agreement with observation in mid to high latitudes, but this is due to compensating errors in humidity and temperature. The severity of heat stress is projected to increase by the end of the century under climate change scenario RCP8.5, reaching unprecedented levels in some regions compared with observations. An analysis of the different factors contributing to the total spread of projected heat stress shows that spread is primarily driven by the choice of GCMs rather than the choice of indicators, even when the simulated indicators are bias-corrected. This supports the utility of the multi-model ensemble approach to assess the impacts of climate change on heat stress.

16. ***Club Climat Agriculture ; DEUXIEME PARTIE : ADAPTATION ; Les nouveautés de la recherche scientifique : Changement climatique et écologie de la santé (Dossier d'actualité n°6, Spécial COP21, 17 novembre 2015)***

Authors:

Olivier Plantard (INRA) ; Laurent Hubert (INRA) ; **Jean-François Guégan (IRD)**

Summary:

Climat et santé sont liés. La santé humaine, végétale ou animale est soumise à la saisonnalité du climat. S'il change, la saisonnalité des maladies devrait également évoluer. Dès lors, se pose la question des conséquences sanitaires du changement climatique. Sont-elles toujours négatives, comme certains articles alarmistes le laissent penser ? La situation est complexe et donc plus nuancée. Certes, des événements extrêmes, tels que les canicules, les inondations ou les tempêtes

violentes, se feront plus intenses et plus fréquents dans les années à venir, et pourraient générer un impact défavorable accru et une baisse de l'efficacité des systèmes sanitaires, notamment dans les zones les plus fragiles du monde. Néanmoins, cet impact reste difficile à estimer, car il est difficile de prévoir la fréquence de tels événements de nature rare.
Une autre conséquence attendue du changement climatique sur la santé concerne la modification des risques environnementaux, via une exposition accrue au rayonnement ultraviolet ou à des polluants atmosphériques, tels que l'ozone. Certains effets seront néfastes, mais d'autres pourraient se révéler positifs, en faisant disparaître dans certaines régions, des virus, des bactéries ou des champignons parasites. Là encore, l'impact général demeure incertain.

17. ***Regional-scale climate-variability synchrony of cholera epidemics in West Africa (BMC Infectious Diseases 2007, 7:20 doi:10.1186/1471-2334-7-20, © 2007 Constantin de Magny et al; licensee BioMed Central Ltd.)***

Authors:
Guillaume Constantin de Magny, **Jean-François Guégan (IRD), Michel Petit (IRD)** and Bernard Cazelles

Abstract:

Background:
The relationship between cholera and climate was explored in Africa, the continent with the most reported cases, by analyzing monthly 20-year cholera time series for five coastal adjoining West African countries: Côte d'Ivoire, Ghana, Togo, Benin and Nigeria.

Methods:
We used wavelet analyses and derived methods because these are useful mathematical tools to provide information on the evolution of the periodic component over time and allow quantification of non-stationary associations between time series.

Results:
The temporal variability of cholera incidence exhibits an interannual component, and a significant synchrony in cholera epidemics is highlighted at the end of the 1980's. This observed synchrony across countries, even if transient through time, is also coherent with both the local variability of rainfall and the global climate variability quantified by the Indian Oscillation Index.

Conclusion:
Results of this study suggest that large and regional scale climate variability influence both the temporal dynamics and the spatial synchrony of cholera epidemics in human populations in the Gulf of Guinea, as has been described for two other tropical regions of the world, western South America and Bangladesh.

18. ***Predicting Dengue Fever Outbreaks in French Guiana Using Climate Indicators (PLOS Neglected Tropical Diseases | DOI:10.1371/journal.pntd.0004681 April 29, 2016, Copyright: © 2016 Adde et al.)***

Authors:
Antoine Adde, Pascal Roucou, **Morgan Mangeas (IRD)**, Vanessa Ardillon, Jean-Claude Desenclos, Dominique Rousset, Romain Girod, Sébastien Briolant, Philippe Quenel, Claude Flamand

Summary:

Climatic determinants are amongst the most frequently cited in studies aimed at understanding and explaining the dynamics of vector-borne infections, and dengue in particular.
French Guiana, a French overseas territory in which the vector Aedes aegypti is well established, experiences an epidemic cycle of dengue with large and prolonged epidemics occurring approximately every 3 years. Dengue is one of the most prioritized infectious diseases, and it requires an intense mobilization of local public health authorities, health services, and health professional and vector control services. A specific surveillance, preparedness and response plan has been developed based upon these needs. Gaining an accurate understanding of the drivers of dengue transmission is required to develop a model to predict the risk of an epidemic and to plan activities aimed at controlling it.
Here, we assessed the effects of climatic factors on dengue spread to develop a predictive model of the epidemics in French Guiana on a country-wide scale. The goal of the model is to anticipate and plan both preventive and control activities. Given climate conditions, the model predicts that a dengue epidemic is likely to occur in early 2016. These conditions, which are favorable for Aedes mosquito proliferation, could also enhance the diffusion of other arboviruses, such as the Zika virus, in northeastern South America.

19. Socio-economic and Climate Factors Associated with Dengue Fever Spatial Heterogeneity: A Worked Example in New Caledonia (PLOS Neglected Tropical Diseases | DOI:10.1371/journal.pntd.0004211 December 1, 2015, Copyright: © 2015 Teurlai et al.)

Authors:
Magali Teurlai, **Christophe Eugène Menkès (IRD)**, Virgil Cavarero, **Nicolas Degallier (IRD)**, Elodie Descloux, Jean-Paul Grangeon, Laurent Guillaumot, Thérèse Libourel, Paulo Sergio Lucio, **Françoise Mathieu-Daudé (IRD)**, **Morgan Mangeas (IRD)**

Summary:

Dengue fever is the most important viral arthropod-borne disease worldwide and its geographical expansion during the past decades has been of growing concern for scientists and public health authorities because of its heavy sanitary burden and economic impacts.
In the absence of an effective vaccine, control is currently limited to vector-control measures.
In this context, understanding the sociologic, entomologic and environmental factors underlying dengue dynamics is essential and can provide public health authorities with sound information about control measures to be implemented. In this study, we analyse socio-economic, climatic and epidemiological data to understand the impact of the studied factors on the spatial distribution of dengue cases during epidemic years in New Caledonia, a French island located in the South Pacific. We identify at risk areas, and find that temperature and people's way of life are key factors determining the level of viral circulation in New Caledonia. Hence, communication campaigns fostering individual protection measures against mosquito bites could help reduce dengue burden in New Caledonia.
Using projections of temperature under different scenarios of climate change, we find that dengue incidence rates during epidemics could double by the end of the century, with areas at low risk of dengue fever being highly affected in the future.

20. Seasonal Dynamics of Phlebotomine Sand Fly Species Proven Vectors of Mediterranean Leishmaniasis Caused by Leishmania infantum (PLOS Neglected Tropical Diseases | DOI:10.1371/journal.pntd.0004458 February 22, 2016, Copyright: © 2016 Alten et al.)

Authors:
Bulent Alten, Carla Maia, Maria Odete Afonso, Lenea Campino, Maribel Jiménez, Estela González, Ricardo Molina, **Anne-Laure Bañuls (IRD)**, Jorian Prudhomme, **Baptiste Vergnes (IRD)**, **Celine Toty**

(IRD), **Cécile Cassan (IRD)**, **Nil Rahola (IRD)**, Magali Thierry, **Denis Sereno (IRD)**, Gioia Bongiorno, Riccardo Bianchi, Cristina Khoury, Nikolaos Tsirigotakis, Emmanouil Dokianakis, Maria Antoniou, Vasiliki Christodoulou, Apostolos Mazeris, Mehmet Karakus, Yusuf Ozbel, Suha K. Arserim, Ozge Erisoz Kasap, Filiz Gunay, Gizem Oguz, Sinan Kaynas, Nikoloz Tsertsvadze, Lamzira Tskhvaradze, Ekaterina Giorgobiani, Marina Gramiccia, Petr Volf, Luigi Gradoni

Summary:
Recent projections on global warming indicate a constant rise of temperatures in the Mediterranean subregion in the near-mid future. While this phenomenon already caused geographical expansion of several arthropod-borne diseases, it is likely to affect also temporal parameters of seasonally transmitted diseases such as leishmaniasis, a protozoan infection spread by the bite of phlebotomine sand flies. Phenology of sand flies consists in the periods of emergence of adults and their disappearance from collections following an activity period during warm months, which can be characterized by peaks of abundance. Current phonological observations can be important for continuing investigations on sand fly dynamics that may impact on leishmaniasis transmission in the future. With this aim, partners from eight Mediterranean countries identified sites with documented Leishmania infantum transmission by six different vector species and performed multiannual trappings. From the high number of 56,000 specimens collected throughout an area spanning from Portugal at west to Georgia at east, the current seasonal dynamics of Mediterranean vectors was obtained. Both, period of adults emergence and type of density trend were found to be significantly correlated with latitude or mean annual temperature of trapping sites. At the southernmost latitudes, vector activity started as early as begin of April and ended by late November, showing that the no-risk period of potential exposure to L. infantum lasted only 4 months.

21. Emerging infectious diseases: state of the art and perspectives (ISBN: 978 -2 -11- 008586 -3)

Summary:
Emerging Infectious Diseases (EIDs) result from infection with a microorganism, previously unknown or known for some time but that have springed from changes in host, vector, pathogenicity or drug resistance of a new strain, geographic distribution or environmental conditions. Considering EIDs impacts on social, economical and political decisions and issues in a globalizing world, the present report focused on human EIDs develops four components: EID case-studies, current knowledge about determinants and situations of emergence, surveillance indicators and disease risk assessments in public health, and contribution of social sciences to basic knowledge, forecasting and health policy decisions.
Based on four “strong messages”, a global and interdisciplinary approach, a permanent prospective and expertise group, a generic plan for EID, and an interministery emergency fund, this report suggests 25 recommendations focused on research and training, that should help public health authorities and decision-makers to better respond to EIDs in the future.

Key words:
Infectious diseases, infection, emerging infectious disease, infectious risk, Epidemics

For further information:
Leport Catherine et **Guégan Jean-François** (sous la direction de).
Emerging infectious diseases: state of the art and perspectives
Report edited by the « documentation Française » (2011).

22. Spatio-temporal variability of NDVI–precipitation over southernmost South America: possible linkages between climate signals and epidemics ***(Environ. Res. Lett. 3 (2008) 044008 (9pp) doi:10.1088/1748-9326/3/4/044008)***

Authors:
YM Tourre, **L Jarlan (IRD),** J-P Lacaux**,** C H Rotela and M Lafaye

Abstract:
Climate–environment variability affects the rates of incidence of vector-borne and zoonotic diseases and is possibly associated with epidemics outbreaks. Over southernmost South America the joint spatio-temporal evolution of climate–environment is analyzed for the 1982–2004 period. Detailed mapping of normalized difference vegetation index (NDVI) and rainfall variability are then compared to zones with preliminary epidemiological reports. A significant quasi-biennial signal (2.2- to 2.4-year periods, or QB) for joint NDVI–rainfall variability is revealed. From rotated EOFs, dominant NDVI patterns are partitioned according to their lead frequencies: (1) the 'QB group' (2.1-to 3-year periods) includes six modes over southern Brazil, Uruguay, northern-central Argentina (two modes), the southern Paraguay–northern Argentina border, and the Santa Cruz Province; (2) the QB1 (2.4- to 3-year periods) + quasi-quadrennial (QQ) mode over the Misiones Province; and (3) the QB2 (2.1- to 2.5-year periods) + QQ + inter-annual (IA) (3- to 7-year periods) two modes over south-eastern Argentina. Modes within the 'QB group' are positively correlated with global climate signals and SST. The Uruguayan mode is correlated with global ENSO (8-month lag) whilst the southern Entre-Rios/northern Buenos Aires provinces are correlated with central equatorial Pacific SSTs (3-month lag). The Santa Cruz (Patagonia) Province is most correlated with the Pacific
South America (PSA) index and SST patterns (3-month lag) along the Antarctica circumpolar current. The spatial distribution of lead NDVI modes includes the Formosa, Misiones, Chaco and Buenos Aires provinces among others, known for being prone to vector-borne epidemics such as dengue fever, malaria, leishmaniasis (American cutaneous leishmaniasis or ACL), hantivirus, chagas and Argentine hemorrhagic fever (AHF). Some provinces also correspond to regions where lead NDVI PCs' modes are associated with high-frequency climate signals such as the quasi-biennial oscillation in northwest Argentina. The joint preliminary results (climate–environment–public health reports) presented here for the first time are meant: (1) to contribute to a better understanding of climate–environment–epidemics process-based and modeling studies and (2) to facilitate, in the long run, the implementation of local and regional health early warning systems (HEWS) over southernmost South America. The latter is becoming crucial with ever-increasing migration, urban sprawl (re-emergence of dengue fever epidemics since the late 1990s), all embedded in a climate change context.

Keywords: climate and environment, NDVI, epidemics, southernmost South America

23. Health can help saving negotiation on climate change ***(www.thelancet.com Vol 385 June 13, 2015)***

Group of 14 signatories including:
Antoine Flahault, Stefanie Schütte**, Jean-François Guégan (IRD)**, Mathilde Pascal, Robert Barouki, and Rajae El Aouad (University Mohammed V, Rabat, Morocco), Pierre Fournier (School of Public Health, University of Montreal, Montreal, Canada), Yves Coppieters (School of Public Health, University Libre de Bruxelles, Brussels, Belgium), Man-Koumba Soumahoro (Institut Pasteur, Abidjan, Côte d'Ivoire), Sidi Coulibaly (Ministry of Health, Ouagadougou, Burkina Faso), Ammar Abdo (Institut Supérieur des Sciences de la Santé, Djibouti), Francelyne Marano (CNRS UMR Université Paris Diderot, France), France Wallet (EDF, Levallois-Perret, France), Sylvia Medina (Institut de Veille Sanitaire, Saint Maurice, France).

24. *Spatio-temporal Patterns and Landscape-Associated Risk of Buruli Ulcer in Akonolinga, Cameroon* *(Landier J, Gaudart J, Carolan K, Lo Seen D, Gue´gan J-F, et al. (2014) Spatio-temporal Patterns and Landscape-Associated Risk of Buruli Ulcer in Akonolinga, Cameroon. PLoS Negl Trop Dis 8(9): e3123. doi:10.1371/journal.pntd.0003123)*

Authors :
Jordi Landier, Jean Gaudart, Kevin Carolan, Danny Lo Seen, **Jean-François Guégan (IRD)**, Sara Eyangoh, Arnaud Fontanet, Gaëtan Texier

Abstract:

Background:
Buruli ulcer (BU) is an extensively damaging skin infection caused by Mycobacterium ulcerans, whose transmission mode is still unknown. The focal distribution of BU and the absence of interpersonal transmission suggest a major role of environmental factors, which remain unidentified. This study provides the first description of the spatiotemporal variations of BU in an endemic African region, in Akonolinga, Cameroon. We quantify landscape-associated risk of BU, and reveal local patterns of endemicity.

Methodology/Principal Findings:
From January 2002 to May 2012, 787 new BU cases were recorded in 154 villages of the district of Akonolinga. Incidence per village ranged from 0 (n = 59 villages) to 10.4 cases/1000 person.years (py); median incidence was 0.4 cases/1,000py. Villages neighbouring the Nyong River flood plain near Akonolinga town were identified as the highest risk zone using the SPODT algorithm. We found a decreasing risk with increasing distance to the Nyong and identified 4 time phases with changes in spatial distribution. We classified the villages into 8 groups according to landscape characteristics using principal component analysis and hierarchical clustering. We estimated the incidence ratio (IR) associated with each landscape using a generalised linear model. BU risk was highest in landscapes with abundant wetlands, especially cultivated ones (IR = 15.7, 95% confidence interval [95%CI] = 15.7[4.2–59.2]), and lowest in reference landscape where primary and secondary forest cover was abundant. In intermediate-risk landscapes, risk decreased with agriculture pressure (from IR[95%CI] = 7.9[2.2–28.8] to 2.0[0.6–6.6]). We identified landscapes where endemicity was stable and landscapes where incidence increased with time.

Conclusion/Significance:
Our study on the largest series of BU cases recorded in a single endemic region illustrates the local evolution of BU and identifies the Nyong River as the major driver of BU incidence. Local differences along the river are explained by wetland abundance and human modification of the environment.

25. *L'étude des risques sanitaires liés à l'eau dans l'environnement urbain: l'exemple de la ville de Chennai, Inde du Sud* *(Sociétés, environnements, santé, IRD Éditions, Collection Objectifs Suds, Marseille, 2010, © IRD, 2010, ISBN: 978-2-7099-1694-3, ISSN : 1958-0975)*

Authors :
Bernard MONDET, Thomas SEYLER, Gérard SALEM, **Jean-Paul GONZALEZ (IRD, retraité)**

Summary :
Ces premières études portent sur la vulnérabilité, l'exposition et l'adaptation des populations humaines à leur environnement et aux pathologies circulantes. Celles sur la vulnérabilité ont pour base une cartographie dans le temps et dans l'espace des infections liées à l'eau. L'exposition est mise en évidence par la description dynamique de l'environnement urbain et périurbain, à la fois

physique (saisons, microclimats, infrastructures, habitats, collections d'eau), biologique (gîtes larvaires des vecteurs, dynamique des populations de rongeurs, répartition des agents pathogènes) et social (niveau des revenus, appartenance à une caste, mobilité, accès aux soins de santé). Les données obtenues permettront de repérer, pour chacune de ces catégories, des facteurs déterminant l'inégalité face au risque d'infection. Enfin, les populations humaines urbaines possèdent des comportements d'adaptation variables qui dépendent de multiples facteurs qu'il faudrait caractériser.
Il s'agit donc d'étudier et d'analyser la perception du risque (KUMAR *et al.,* 2003) en relation avec les maladies existantes et celles émergentes, puis de rechercher les types de réactions à court et moyen termes les mieux adaptés au contexte social.

L'objectif ultime de cette étude, conduite via une approche intégrée, interdisciplinaire et systémique, est le développement d'un système d'alerte précoce.

Le changement climatique constitue l'un des éléments étudiés dans le cadre de l'étude en tant que phénomènes pouvant impacter l'émergence de maladies infectieuses.

Pour mieux appréhender la structure complexe d'une telle étude, l'étude est basée sur un exemple concret, celui de la ville de Chennai, anciennement Madras, capitale de l'État du Tamil Nadu en Inde du Sud.

26. Changements environnementaux et maladies infectieuses : mieux coordonner la surveillance (adsp n° 93 décembre 2015)

Authors :

Jean-François Guégan, Directeur de recherche, à l'Institut de recherche, pour le développement, UMR MIVEGEC IRDCNRS-Université de Montpellier, conseiller scientifique initiative *ecoHEALTH* du programme international *Future Earth* des Nations Unies, ancien membre du HCSP, président de la partie santé du Plan national d'adaptation au changement climatique (2011-2015)

Frédéric Simard
Directeur de recherche à l'Institut de recherche pour le développement, directeur de l'UMR MIVEGEC IRD-CNRS Université de Montpellier

Introduction :
Des 1 417 maladies infectieuses dues à des virus, bactéries ou parasites, connues dans la population humaine mondiale, seules les 174 (12,27 %) maladies participant le plus largement à la mortalité et à la morbidité générale offrent des informations plus ou moins renseignées sur leur distribution spatiale. Curieusement, seulement 7 d'entre elles (4 % des 174 renseignées) possèdent une cartographie générale suffisamment exhaustive permettant de comprendre les multiples facteurs, dont biogéographiques, écologiques et climatiques qui participent à leur installation et à leur répartition.
Le paludisme, et en particulier celui causé par le protozoaire *Plasmodium falciparum*, est à l'heure actuelle la maladie humaine la mieux cartographiée.
Avec les changements climatiques, les inquiétudes sont croissantes quant à une colonisation progressive du continent européen par des agents infectieux, plus particulièrement ceux véhiculés par des arthropodes, comme les moustiques des genres *Aedes*, *Anopheles* ou *Culex*, ou encore par des acariens, comme les tiques.
La possibilité d'invasion de nos territoires européens par des animaux réservoirs, ou leurs agents pathogènes ou parasites, existe – comme l'a révélé l'installation d'un foyer de bilharziose à *Schistosoma haematobium* dans la rivière Cavu en Corse du Sud en 2014. La surveillance de ce type

d'invasion biologique demeure aisée à réaliser, essentiellement parce que les animaux impliqués sont soit plus facilement identifiables soit parce qu'ils peuvent également intéresser les naturalistes.
Pourquoi alors clamer une implication des changements climatiques dans l'émergence ou la ré-émergence de maladies vectorielles ou zoonotiques en Europe lorsque finalement pour un très grand nombre d'entre elles, les aires de distribution possibles ou probables sont peu ou pas étudiées ? Assistera-t-on à des épidémies infectieuses plus importantes sur le territoire métropolitain comme, par exemple, des gastro-entérites virales ou bactériennes, et quels en seraient les facteurs responsables ? Comment peut-on répondre empiriquement à l'implication des changements climatiques sur l'apparition de ces maladies en Europe ? Quelle(s) adaptation(s) doit effectuer aujourd'hui la surveillance épidémiologique à la lumière des développements conséquents effectués en recherche internationale sur ces sujets ? Enfin, dans l'écheveau des différents facteurs imbriqués les uns dans les autres et où les notions d'interactions, de synergies et d'antagonismes prennent tout leur sens, comment démêler toutes les causes en admettant la réalité du problème climatique de plus en plus inquiétant ?

Conclusion :

La thématique des effets du dérèglement climatique sur la distribution géographique des maladies infectieuses, et en particulier de celles à transmission indirecte, n'a jamais été aussi présente, mais la manière dont elle est abordée pose encore problème. Dans la majorité des situations étudiées persiste une confusion : le risque infectieux résulte de la confrontation entre une association de phénomènes menaçants, ou aléa(s), et une population humaine, ou animale. Une assimilation trop rapide est encore faite dans les travaux scientifiques entre la présence et la distribution géographique d'arthropodes potentiellement vecteurs d'agents pathogènes – conçues comme la menace à part entière – et le véritable risque infectieux. En effet, l'importance du risque infectieux dépend d'un ou des aléas quant à leur nature – l'insecte capable de transmettre un agent infectieux est un élément nécessaire mais pas suffisant –, leur intensité et leur probabilité, des populations humaines, ou animales, exposées et de leur vulnérabilité. L'évolution des recherches en la matière devra donc mieux prendre en compte l'ensemble des menaces sanitaires, y incluant l'agent pathogène dans ses interactions avec l'ensemble du système infectieux, les enjeux humains ou animaux exposés et les politiques publiques mises en œuvre pour limiter ou contrôler les effets d'un ou des aléas.
Ces futurs travaux devront aussi traiter par ailleurs des effets des changements climatiques intervenant à la fois sur les menaces infectieuses et les enjeux d'exposition.
Au final, en filigrane à ce texte, il conviendra aussi que l'épidémiologie et la santé publique s'interrogent aujourd'hui sur ce que ces disciplines intitulent « études écologiques » c'est-à-dire la mise en évidence de corrélations statistiques. Car, en effet, les sciences écologiques ont depuis trente années évolué, et ont développé des protocoles expérimentaux ou d'échantillonnage rigoureux tout en assurant des développements conséquents en modélisation biomathématique et tests d'hypothèses. Si le dérèglement climatique risque d'impacter de nombreux territoires et populations, épidémiologie–santé publique et écologie doivent aussi savoir aujourd'hui en bénéficier en unissant leurs approches respectives pour étudier et comprendre les conséquences sanitaires des changements environnementaux planétaires.

27. ***Climate drives the meningitis epidemics onset in West Africa*** (Plos Medicine, *2005, 2 (1), p. 43-49. ISSN 1549-1277 ; **doi:10.1371/journal.pmed.0020006**)

Authors :

Benjamin Sultan (IRD), Karima Labadi, **Jean-François Guégan (IRD), Serge Janicot (IRD)**

Abstract :

Background :

Every year West African countries within the Sahelo-Sudanian band are afflicted with major meningococcal meningitis (MCM) disease outbreaks, which affect up to 200,000 people, mainly young children, in one of the world's poorest regions. The timing of the epidemic year, which starts in February and ends in late May, and the spatial distribution of disease cases throughout the "Meningitis Belt" strongly indicate a close linkage between the life cycle of the causative agent of MCM and climate variability. However, mechanisms responsible for the observed patterns are still not clearly identified.

Methods and Findings:

By comparing the information on cases and deaths of MCM from World Health Organization weekly reports with atmospheric datasets, we quantified the relationship between the seasonal occurrence of MCM in Mali, a West African country, and large-scale atmospheric circulation. Regional atmospheric indexes based on surface wind speed show a clear link between population dynamics of the disease and climate: the onset of epidemics and the winter maximum defined by the atmospheric index share the same mean week (sixth week of the year; standard deviation, 2 wk) and are highly correlated.

Conclusions:

This study is the first that provides a clear, quantitative demonstration of the connections that exist between MCM epidemics and regional climate variability in Africa. Moreover, this statistically robust explanation of the MCM dynamics enables the development of an Early Warning Index for meningitis epidemic onset in West Africa. The development of such an index will undoubtedly help nationwide and international public health institutions and policy makers to better control MCM disease within the so-called westward–eastward pan-African Meningitis Belt.

Annex 2: IRD's research units and researchers involved in the field of climate and health (in French)

Liste des unités de recherche et chercheurs ayant contribué à des travaux sur la thématique santé et climat

1. *Biodiversité marine, exploitation et conservation - (MARBEC)*

Département : Département Océans, climat et ressources (OCEANS)
Unités mixtes de recherche : IRD / Institut français de recherche pour l'exploitation de la mer/ Université Montpellier/ Centre national de la recherche scientifique

Implantations en métropole : Station Ifremer, Sète, France, et Université Montpellier, France
Implantations hors métropole :

- Seychelles Fishing Authority (SFA), Victoria, Seychelles
- Instituto del Mar del Perú (IMARPE), Lima, Pérou
- Université de La Réunion, Campus du Moufia, Saint-Denis, La Réunion
- Semir, Le Port, La Réunion
- Université de Cape Town (UCT), Le Cap, Afrique du Sud
- Centre de recherches océanologiques (CRO) – Abidjan – Côte d'Ivoire
- Institute of Biotechnology - Vietnam Academy of Science and Technology (IBT) - Hanoï – Nha Trang - Vietnam
- Labep-Ao-Ifan - Ucad - Dakar - Sénégal
- Faculté des sciences de Bizerte - Tunis - Tunisie
- Central Research Institute for Aquaculture (CRIA) – Jakarta - Indonésie

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Contribution à: (i) Options for water storage and rainwater harvesting to improve health and resilience against climate change in Africa (Received: 21 December 2010 / Accepted: 29 January 2012 /Published online: 25 February 2012, Springer-Verlag 2012)
(ii) Health Impacts of Small Reservoirs in Burkina Faso (IWMI Working Paper 136, ISSN 2012-5763, ISBN 978-92-9090-717-6, Copyright © 2009, by IWMI)

2. *Biologie des organismes et écosystèmes aquatiques - (BOREA)*

Département : Département Ecologie, Biodiversité et Fonctionnement des Ecosystèmes Continentaux (ECOBIO)
Unités mixtes de recherche : IRD / Centre national de la recherche scientifique/ Muséum National d'Histoire Naturelle/ Université Pierre et Marie Curie - Paris 6/ Université de Caen Normandie/ Université des Antilles et de Guyane

Implantations en métropole : Muséum national d'Histoire naturelle, Paris, France
Implantations hors métropole :

- Universidad Mayor de San Simon (UMSS) - Cochabamba - Bolivie

- Instituto de Investigaciones de la Amazonia Peruana (IIAP) – Iquitos – Pérou
- IRD-Cayenne – Guyane

Site web: www.borea.mnhn.fr

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Contribution à: Complex temporal climate signals drive the emergence of human water-borne

3. Centre d'études spatiales de la biosphère - (CESBIO)

Département : Département Dynamiques Internes et de Surface des Continents (DISCO)
Unités mixtes de recherche : IRD / Centre National d'Etudes Spatiales/ Centre national de la recherche scientifique/ Université Paul Sabatier - Toulouse 3

Implantation en métropole : Université Paul-Sabatier, Toulouse, France
Implantations hors métropole :

- Institut national agronomique de Tunisie (INAT) - Tunis - Tunisie
- Université Cadi Ayyad - Marrakech - Maroc
- CNRS Liban - Beyrouth - Liban

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Contribution à: Spatio-temporal variability of NDVI–precipitation over southernmost South America: possible linkages between climate signals and epidemics (Environ. Res. Lett. 3 (2008) 044008 (9pp) doi:10.1088/1748-9326/3/4/044008)

4. Émergence des pathologies virales - (EPV)

Département : Département Santé et sociétés (SAS)
Unités mixtes de recherche : IRD / Ecole des hautes études en santé publique/ Aix-Marseille Université/ Etablissement français du sang/ Institut national de la santé et de la recherche médicale

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5. *Espace pour le développement - (ESPACE-DEV)*

Département : Département Sociétés et Mondialisation (SOC)
Unités mixtes de recherche : IRD / Université Montpellier/ Université de La Réunion/ Université des Antilles et de la Guyane

Implantation en métropole : IRD-Maison de la télédétection, Montpellier, France
Implantations hors métropole :

- Université de Brasilia - Brésil
- IRD - Cayenne - Guyane
- IRD - Sainte-Clotilde et Saint-Pierre - La Réunion
- IRD - Nouméa - Nouvelle-Calédonie
- Agence gabonaise d'études et d'observations spatiales (AGEOS) - Franceville - Gabon

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(ii) Projet RELAIS et risques d'épidémies en Amérique latine : mieux comprendre les processus qui lient l'environnement à la santé humaine

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(ii) Socio-economic and Climate Factors Associated with Dengue Fever Spatial Heterogeneity: A Worked Example in New Caledonia (PLOS Neglected Tropical Diseases | DOI:10.1371/journal.pntd.0004211 December 1, 2015, Copyright: © 2015 Teurlai et al.)

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Contribution à: Land cover, land use and malaria in the Amazon: a systematic literature review of studies using remotely sensed data (Stefani et al. Malaria Journal 2013, 12:192, http://www.malariajournal.com/content/12/1/192, © 2013 Stefani et al.; licensee BioMed Central Ltd.)

6. *Gestion de l'eau, acteurs et usages - (G-EAU)*

Département : Département Dynamiques Internes et de Surface des Continents (DISCO)
Unités mixtes de recherche : IRD / AgroParisTech/ Institut national de recherche en sciences et technologies pour l'environnement et l'agriculture/ Centre de coopération internationale en recherche agronomique pour le développement/ Montpellier SupAgro

Implantation en métropole : Irstea, Montpellier, France
Implantations hors métropole :

- Institut national agronomique de Tunisie (Inat) - Tunis - Tunisie
- Direction nationale de l'hydraulique de Guinée (DNH) - Guinée Conakry
- Représentation IRD de Bamako - Mali
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Contribution à: Seasonal forecasting for Africa: Water, health management and capacity building
(ISBN 978-0-9568561-3-5, © 2012 Tudor Rose. All rights reserved)

7. *HydroSciences*

Département : Département Dynamiques Internes et de Surface des Continents (DISCO)
Unités mixtes de recherche : IRD / Centre national de la recherche scientifique/ Université Montpellier

Implantation en métropole : Université Montpellier, France
Implantations hors métropole :

- Laboratoire de microbiologie et biologie moléculaire - Faculté des sciences - Rabat – Maroc
- Université Cadi Ayyad – Marrakech - Maroc
- IRD Martinique/Caraïbe - Fort de France - Martinique
- Université de Ngaoundéré – Cameroun
- Université Nangui Abrogoua – Abidjan - Côte d'Ivoire

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Contribution à: Water and public health in Sahelian countries: The case of infectious disease in Saint-Louis (Senegal) (Sécheresse vol. 20, n° 1, janvier-février-mars 2009)

8. *Interactions hôte-vecteur-parasite-environnement dans les maladies tropicales négligées dues aux trypanosomatidés - (INTERTRYP)*

Département : Département Santé et sociétés (SAS)
Unités mixtes de recherche : IRD / Centre de coopération internationale en recherche agronomique pour le développement

Implantation en métropole : CIRAD, Montpellier, France
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- Centre international de recherche-développement sur l'élevage en zone subhumide (Cirdes) - Bobo Dioulasso - Burkina Faso
- Institut Pierre Richet – Bouaké - Côte d'Ivoire
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9. *Laboratoire d'océanographie et du climat : expérimentations et approches numériques - (LOCEAN)*

Département : Département Océans, climat et ressources (OCEANS)
Unités mixtes de recherche : IRD / Centre national de la recherche scientifique/ Muséum National d'Histoire Naturelle/ Université Pierre et Marie Curie - Paris 6

Implantation en métropole : Université Pierre et Marie Curie, Paris, France
Implantations hors métropole :

- Universidade Federal do Ceara (UFC) - Fortaleza - Brésil
- Universidad Peruana Cayetano Heredia (UPCH) - Lima - Pérou
- Instituto del Mar del Peru (IMARPE) - Lima - Pérou
- IRD - Nouméa - Nouvelle-Calédonie
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Contribution à: Climate drives the meningitis epidemics onset in West Africa

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Contribution à: (i) Estimating heat stress from climate-based indicators: present-day biases and future spreads in the CMIP5 global climate model ensemble (Environ. Res. Lett. 10 (2015) 084013 doi:10.1088/1748-9326/10/8/084013)
(ii) Climate drives the meningitis epidemics onset in West Africa

10. *Maladies infectieuses et vecteurs : écologie, génétique, évolution et contrôle - (MIVEGEC)*

Département : Département Santé et sociétés (SAS)
Unités mixtes de recherche : IRD / Centre national de la recherche scientifique/ Université Montpellier

Implantation en métropole : IRD France-Sud, Montpellier, France
Implantations hors métropole :

- Institut de recherche en sciences de la santé (IRSS), Bobo Dioulasso, Burkina Faso
- Centre de recherche entomologique de Cotonou (CREC), Cotonou, Bénin
- Institut Pierre Richet (IPR), Bouaké, Côte d'Ivoire
- Institut Pasteur de Dakar (IPD), Dakar, Sénégal
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- Kasetsart University, Department of Agricultural and Resource Economics, Bangkok, Thaïlande
- National Institute of Hygiene and Epidemiology, Hanoï, Vietnam
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(ii) Combining Hydrology and Mosquito Population Models to Identify the Drivers of Rift Valley Fever Emergence in Semi-Arid Regions of West Africa (Received March 16, 2012; Accepted July 7, 2012; Published August 21, 2012)

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(ii) Water and public health in Sahelian countries: The case of infectious disease in Saint-Louis (Senegal) (Sécheresse vol. 20, n° 1, janvier-février-mars 2009)

(iii) Combining Hydrology and Mosquito Population Models to Identify the Drivers of Rift Valley Fever Emergence in Semi-Arid Regions of West Africa (Received March 16, 2012; Accepted July 7, 2012; Published August 21, 2012)

(iv) Complex temporal climate signals drive the emergence of human water-borne disease (Emerging Microbes and Infections (2014) 3, e56; doi:10.1038/emi.2014.56_ 2014 SSCC. All rights reserved 2222-1751/14)

(v) Moving towards a new discipline - Health ecology (© Pour la Science - INRA 2015)

(vi) Changement climatique et santé : en a-t-on trop dit ou pas assez ? (2015)

(vii) Club Climat Agriculture ; DEUXIEME PARTIE : ADAPTATION ; Les nouveautés de la recherche scientifique : Changement climatique et écologie de la santé (Dossier d'actualité n°6, Spécial COP21, 17 novembre 2015)

(viii) Regional-scale climate-variability synchrony of cholera epidemics in West Africa (BMC Infectious Diseases 2007, 7:20 doi:10.1186/1471-2334-7-20, © 2007 Constantin de Magny et al; licensee BioMed Central Ltd.)

(ix) Emerging infectious diseases: state of the art and perspectives (ISBN: 978 -2 -11-008586 -3)

(x) Health can help saving negotiation on climate change (www.thelancet.com Vol 385 June 13, 2015)

(xi) Spatio-temporal Patterns and Landscape-Associated Risk of Buruli Ulcer in Akonolinga, Cameroon (Landier J, Gaudart J, Carolan K, Lo Seen D, Gue´gan J-F, et al. (2014) Spatio-temporal Patterns and Landscape-Associated Risk of Buruli Ulcer in Akonolinga, Cameroon. PLoS Negl Trop Dis 8(9): e3123. doi:10.1371/journal.pntd.0003123)

(xii) Changements environnementaux et maladies infectieuses : mieux coordonner la surveillance (adsp n° 93 décembre 2015)

(xiii) Climate drives the meningitis epidemics onset in West Africa

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(ii) Changements environnementaux et maladies infectieuses : mieux coordonner la surveillance (adsp n° 93 décembre 2015)

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Contribution à: Seasonal Dynamics of Phlebotomine Sand Fly Species Proven Vectors of Mediterranean Leishmaniasis Caused by Leishmania infantum (PLOS Neglected Tropical Diseases | DOI:10.1371/journal.pntd.0004458 February 22, 2016, Copyright: © 2016 Alten et al.)

11. *Observatoire de recherche méditerranéen de l'environnement - (OREME)*

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13. Autres rattachements

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