18 Climate Change and Global Health: A Latin American Perspective

Ulisses Confalonieri,[1] Germán Poveda,[2] Horacio Riojas,[3] Marilyn Aparicio Effen[4] and Ana Flávia Quintão[5]

[1]CPqRR – Fundação Oswaldo Cruz (FIOCRUZ), LAESA, Minas Gerais, Brazil; [2]Department of Geosciences and Environment, Universidad Nacional de Colombia, Medellín, Colombia; [3]Instituto Nacional de Salud Pública, Cuernavaca Morelos, México; [4]Climate Change, Environmental and Health Unit, Instituto Boliviano de Biologia de Altura (IBBA), Universidad Mayor de San Andrés, Bolivia; [5]Escola de Saúde Pública do Estado de Minas Gerais (ESP-MG), Minas Gerais, Brazil

18.1 Introduction

Latin America (LA) is a very heterogeneous region, with 41 countries covering 20,393,600 km^2. The total population in 2011 was about 600 million; about 93% of whom had access to safe water supplies and 79% were provided with some type of waste disposal facilities (Pan American Health Organization (PAHO), 2011). It is considered the most urbanized region in the world; almost 80% of its population lives in cities; 14% of whom live in megacities (UN Habitat, 2012).

The epidemiological profile of LA is marked by diseases of poverty and underdevelopment. As a consequence of the strong historical and current socio-economic inequalities found in Latin American countries, conditions such as diarrhoea and respiratory infections in children still constitute a serious problem in many regions. Among the socio-environmental diseases are those arising from water shortage and pollution, indoor and outdoor air pollution, exposure to chemical substances and, recently, those attributable to climate variability, climate change and natural disasters (Magrin *et al*, 2014). As yet, there is no precise estimate of the morbidity and mortality attributable to this last factor. Recent studies have tried to demonstrate the link between the deterioration of ecosystems and public health problems in LA (Riojas-Rodriguez *et al*., 2010). Chronic illnesses such as diabetes and cardiovascular diseases also contribute significantly to this epidemiological profile.

Globalization has introduced, accelerated or triggered health problems in LA. Examples span from influenza epidemics to transboundary chemical pollution throughout the continent. The climate crisis has contributed to the generation of problems in the region, such as food insecurity (in many Central American countries); mobilization of vectors toward sites where they were not found previously (as in Bolivia); increases in exposure to air pollutants such as ozone resulting from changing temperature patterns (as in Mexico City); and increases in morbidity and mortality as a consequence of extreme hydrometeorological events across the region.

In 2010, about 3% of the regional population was exposed to the risk of malaria transmission (637,801 cases of malaria were reported, with 1.7 million cases of dengue fever; PAHO, 2011).

Global health solutions require highly inter and multidisciplinary approaches, focussing on issues that can transcend national boundaries. This also implies solutions based on a global cooperation aimed at health equity among all nations and for all people (Koplan *et al.*, 2009).

Recently, a Latin American Alliance for Global Health was formed as a collaborative network between regional public health institutions. Its major aim is to address global health issues considered as priorities for the LA region, to be approached as a public good informed by social justice and universal rights. Workshops and meetings are being organized periodically to tackle broad themes such as the impacts of the economic crisis, population displacements, universal coverage of health services, disaster management and global climate change (www.saludglobal.uchile.cl).

18.2 Natural Disasters and Extreme Weather Events

Diverse climate change impacts are already being observed in the region. These include changes in hurricane intensity and frequency in the Caribbean, alterations in precipitation patterns and in temperature levels and increased droughts. Additionally, rising sea levels affect coastal LA; glaciers in Patagonia and the Andes are receding; and ice sheets in West Antarctica are shrinking (Programa de las Naciones Unidas para el Medio Ambiente (PNUMA) *et al.*, 2010). In Andean countries, glacial retreat is reducing the quality and availability of drinking water, and also threatens hydroelectricity supply. In Bolivia, 80% of glaciers are retreating, for example the Chacaltaya glacier shrank from 0.22 km^2 of surface ice in 1940 to only 0.01 km^2 in 2005.

One of the most important impacts of climate change is to drinking water availability in major cities, caused by altered rainfall patterns. For La Paz, future climate scenarios indicate drier dry seasons and rainy seasons with small increases in water availability. Water systems in two neighbourhoods in La Paz are more sensitive to an imbalance between supply and demand from demographic processes, and three are more sensitive to an imbalance of supply and demand owing to the potential short-term disappearance of glaciers (Aparicio *et al.*, 2013a).

In Bolivia, owing to its high vulnerability and topography, extreme climatic events are harming economic development and investment. The 1997/98 El Niño generated economic disasters in Bolivia, with losses totalling US$530 million, equivalent to 7% of gross domestic product (GDP) (CEPAL, 2007).

Climate change is also reinforcing the intensity and frequency of climate variability, with more intense events, associated with either pole of the El Niño–Southern Oscillation (ENSO). Floods and droughts have become more extreme in Bolivia and nearby countries such as Peru and Ecuador. Although more recent ENSO cycles have been moderate, their impacts were still significant in Bolivia (Arana *et al.*, 2007a). Extreme weather events recurrent in urban and rural areas manifested as flooding, landslides, droughts, snowstorms, windstorms and hailstorms, as in La Paz, and seem to be increasing (see Fig. 18.1).

On 19 February 2002, a rainfall of 70 mm in 45 min, with hail, overwhelmed all drainage systems in La Paz, leading to flash floods, with 70 deaths, 19 missing and many persons injured (Arana *et al.*, 2007b). This event generated the creation of an early warning system (EWS) by the La Paz municipal government.

On 26 February 2011, La Paz, at 3640 m above sea level, a city in a mountainous ecosystem, suffered a huge landslide, affecting nine neighbourhoods and causing significant economic damage. On 24 and 25 February, street cracks preceded the landslide, triggering the EWS and neighbourhood evacuation. It was the rainiest February since 1919, with 25 wet days. Also contributing to the landslide were saturated soil and possible uncontrolled sanitary discharges (Aparicio *et al.*, 2013b).

Extreme climate events can also have important other public health consequences, including crop destruction, population relocation and damage to health systems infrastructure.

Better civil protection alert systems have decreased mortality from hurricanes; however, the number of people affected and displaced has increased, especially since the 1990s, probably due mainly to population increase. The effects of extreme weather events (EWEs), however, in the intermediate and long term have not been quantified adequately. Some Central American studies

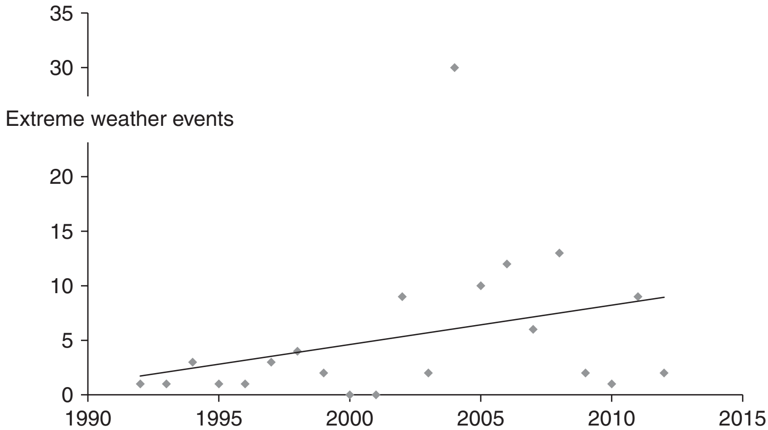

Fig. 18.1. Extreme weather events in La Paz, Bolivia, 1992–2012 (Aparicio *et al.*, 2013b).

show the impact of EWEs on food safety, especially in the degree of undernutrition found in children after these events (Barrios *et al.*, 2000).

The number of storms between 2000 and 2009 has multiplied by 12, and the number of floods has quadrupled since the 1970s. The number of people affected by extreme temperatures, storms, droughts and forest fires has increased from 5 million during the 1970s to 40 million during the past decade (PNUMA *et al.*, 2010).

Statistics on the health impacts of disasters (Centre for Research on the Epidemiology of Disasters (CRED), 2011) indicate that during 2000–2010 around 630 weather and climate extreme events occurred in LA, resulting in about 16,000 deaths among 46.6 million people affected, with losses of US$208 million.

The effects of climate change and climate variability are also being felt strongly in Colombia. Massive floods during 2010–2012, caused by climate change, La Niña and excessive deforestation, resulted in hundreds of deaths and thousands of displaced people, with infrastructure and agricultural losses (Poveda *et al.*, 2011a,b).

A 1991–2010 Civil Defence Report (Brazil, 2012) for Brazil found that 73% of all accidents related to EWEs since 1991 occurred between 2000 and 2010. Most deaths (n = 3404) related to these events were associated with landslides (41%) – usually resulting from heavy rains – and floods (42.9%). Casualties were concentrated in the densely populated south-eastern region, with 20 deaths/million: 69% of all disaster-related deaths in the country.

18.3 Infectious Diseases

Climatic variables and EWEs provide the ecological preconditions for an augmented risk of infectious disease transmission via vectors and hosts (Team and Manderson, 2011). Climate variability associated with both phases of ENSO have affected the incidence of diverse tropical and infectious diseases significantly in LA, including malaria, dengue, leishmaniasis (cutaneous and visceral), yellow fever, cholera, diarrhoea and probably Chagas disease. Climate change is now triggering the increase, persistence and re-emergence of some diseases in non-endemic areas, including some once considered eliminated, eradicated or controlled (Rodriguez-Morales *et al.*, 2010).

The recession of Andean tropical glaciers is modifying the geographic range of different species, with consequences to infectious diseases. Natural habitats are receding and disappearing, and imbalances between species and their predators are altering food chains. The modified plant and animal biodiversity has created suitable habitats for vector development, resulting in an increasing incidence of vector-borne diseases at higher altitudes, including malaria in non-traditional endemic areas (Aparicio *et al.*, 2010). Microorganisms and Chagas disease vectors including *Tripanosoma cruzi* and *Triatoma* *infestans* are adapting rapidly to the higher altitudes of mountain ecosystems, with new cases reported at 2800–3000 m in La Paz (Aparicio *et al.*, 2010).

Heavier rainfalls and drier seasons are altering human behaviour, increasing home water storage, further enhancing mosquito habitat and risking biological water contamination. Since 1998, the dengue seasonality for Santa Cruz, Bolivia, has extended from January to May, peaking in March or April (Aparicio *et al.*, 2010).

Dengue fever serotype 1 re-emerged in Bolivia between 1987 and 1998, coincident with strong ENSO events. Serotype 2 produces many dengue cases, considering that actual climate is warmer than the baseline, predominantly in the summer months. The relationship between climate, weather and dengue is being analysed to develop EWSs. In Santa Cruz, Bolivia, average and minimum temperature thresholds combined with weekly rainfall thresholds for the same period were found to be good predictors for dengue outbreaks, if fitted with a 5-week lag period (Arana *et al.*, 2007a).

Carbajo *et al.* have evaluated the role played by climate in the epidemiology of dengue in Argentina (1998–2011) (Carbajo *et al.*, 2012). By modelling annual risk using a temperature-based mechanistic model, they found that temperature, although useful to estimate annual transmission risk, did not describe dengue occurrence adequately at the country level. Climatic variables separately performed worse than geographic or demographic ones.

Using historical, climatic and epidemiological data sets, diverse studies have investigated the effects of El Niño events on the distribution of malaria and dengue in countries such as México, Costa Rica, Argentina and Brazil. In Mexico, the dengue epidemiological curve during cold weather has changed in such a way that incidence is higher than before. Outbreaks of malaria have occurred in unusually high latitudes, such as Bolivia (Rutar *et al.*, 2004). There are also preliminary studies suggesting that climate change will alter the distribution of leishmaniasis (Salomón *et al.*, 2012). In other cases, due to the absence of field study evidence, projections have been made based on possible ecosystem changes associated with climate change and their probable effects on vector distribution, as with Ecuador (Pinault and Hunter, 2012). Other contributions include the use of research findings to develop EWSs for malaria in Colombia (Poveda *et al.*, 2011) and to generate a vulnerability atlas to anticipate better the effects of climate change. For example, in Mexico, infectious diseases (acute diarrhoea) and vector-borne diseases (dengue) are included in this atlas (Riojas-Rodríguez *et al.*, 2012).

The incidence of malaria in Colombia has increased steadily in the past 50 years (see Fig. 18.2). This may be explained by historically increasing trends in average air temperatures, due to local and regional climate change, as well as massive deforestation (Poveda *et al.*, 2011). Additionally, Colombia experiences strong outbreaks of malaria during the warm phase of ENSO events that occur over the central-eastern topical Pacific (Ruiz *et al.*, 2006; Poveda *et al.*, 2011). Malaria in Colombia, as elsewhere, is also influenced by human migration in endemic areas (Osorio *et al.*, 2007; Rodriguez-Morales *et al.*, 2010).

Recent studies have indicated the role of climate-driven river flow variations in the Amazon as contributors to increases in the incidence of malaria in particular localities. Assuming that the precipitation–malaria relationships depend on the surface water conditions, researchers have observed that, while in the uplands, the malaria risk in relation to rainfall is variable, it is negative in areas dominated by wetlands and large rivers, where more precipitation indicates less malaria (Olson *et al.*, 2009). In some municipalities in Amazonas, Brazil, malaria increases have been observed to occur 1–2 months after peaks of temperature, and also a few days after sudden oscillations in river water levels, a hydrological phenomenon known locally as ‘repiquete’ (Wolfhart, 2011).

In 1998, a malaria outbreak near Titicaca Lake in the inter-Andean valleys near La Paz (elevation 2615–3592 m) led to the first local documentation of *Anopheles pseudopunctipennis* associated with new ecosystem conditions that emerged in the context of a changing climate. The current microclimate is 0.85°C warmer than at the baseline (1960–1990) (Aparicio *et al.*, 2013b).

The malaria assessment for Pando, Beni and La Paz, in northern Bolivia, showed an

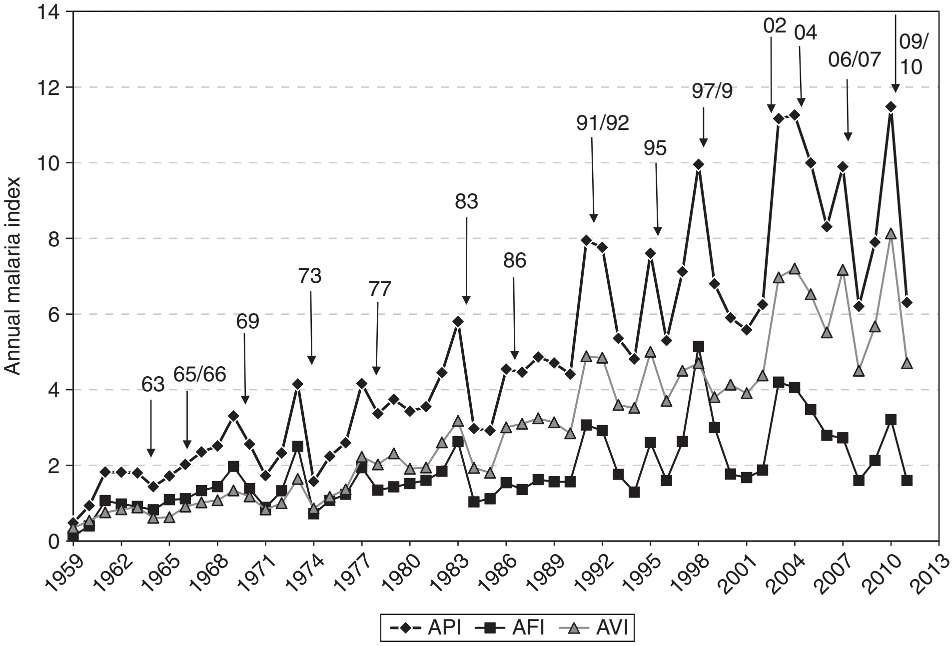

Fig. 18.2. Time series of three malarial indices for Colombia during 1959–2011. The Annual Parasitic Incidence (API) index aggregates malaria caused by *Plasmodium falciparum* (AFI) and *Plasmodium vivax* (AVI). Dates and arrows denote historical El Niño events (http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/ensostuff/ensoyears.shtml). AFI = Annual Falciparum Index; AVI = Annual Vivax Index. (Data: Colombian National Institute of Health (http://www.ins.gov.co/Paginas/inicio.aspx.)

incremental increase since March 1993, caused by *Plasmodium falciparum* and, since April 1994, for cases caused by *Plasmodium vivax*. It was also observed that the climatic factors were found to explain 27.4% of malaria cases (*P. vivax* 11.3% and 43.6% for *P. falciparum*) (Aparicio and Ortiz, 2000).

The tropical Americas have witnessed a marked increase in both classic dengue fever (DF) and dengue haemorrhagic fever (DHF) incidence in the past two decades, imposing an economic burden of around US$2.1 billion/year (2010 US dollars) (Shephard *et al.*, 2011). Environmental and climatic variability affects dengue incidence by increasing vector (*Aedes aegypti*) densities, as has been documented in recent outbreaks in Honduras and Nicaragua (Rodriguez-Morales *et al.*, 2010) and Costa Rica (Mena *et al.*, 2011). Developed and tested predictive spatial ecological models of DF occurrence based on environmental and topographical variables for the metropolitan area of Medellin, Colombia, have good predictive capacity, including for non-sampled areas (Arboleda *et al.*, 2009).

Diarrhoeal diseases are of concern for different reasons: there continues to be a high frequency in poor regions; the bacteria and viruses are sensitive to temperature changes; and, in some regions, food-cooling chains are affected during extreme events. Epidemiological studies have shown an association of increased incidence of 2% for each degree in average temperature rise. Floods, heavy rains and high temperatures have been associated with an incremental rise in the number of people admitted to hospitals with acute diarrhoea. This is caused by high temperatures aiding the proliferation of bacteria and parasites ingested through drinking water (Checkley *et al.*, 2000).

In the state of Pernambuco, Brazil, rainfall intensity is associated with increased rates of infant mortality (Rocha, 2012). In the semi-arid part, low precipitation was linked to higher infant mortality rates, while in the non-arid area, heavy rainfall was positively associated with infant mortality, caused mostly by diarrhoea.

Yellow fever, though vaccine preventable, is endemic in tropical South America below an elevation of 2300 m, owing to climatic and environmental conditions. In 2003–2004, Colombia witnessed the largest outbreak of yellow fever in 50 years: more than 200 cases and 50 deaths were reported in rural areas, with a high risk of the epidemic reaching urban areas.

Schistosomiasis is a prevalent neglected tropical disease (NTD) in South America, mostly in Brazil, Suriname, Venezuela and the Andes. Ambient temperatures affect its distribution and prevalence, which is likely to alter due to climate change (Mangal *et al.*, 2008). Schistosomiasis is also likely to increase its local infection and geographic range with climate change (Mas-Coma *et al.*, 2009).

Cutaneous leishmaniasis (CL) is a parasitic endemic cutaneous disease transmitted to human and other mammal hosts by the bite of phlebotomine sandflies. The disease is associated with climatic factors in LA, including ENSO. Bolivia exhibits a high incidence of CL, with 33 cases/100,000 inhabitants. In the 1990s, the disease increased markedly during La Niña, but fell by 40% during El Niño years (Gomez *et al.*, 2006). Climatic variability was considered responsible for the occurrence of 34% of new leishmaniasis cases in northern Bolivia (Aparicio and Ortiz, 2000). The impact of interannual ENSO variability on the incidence of cutaneous and visceral leishmaniasis (VL) in Colombia during 1985–2002 has also been studied. Contrary to Bolivia, researchers found that leishmaniasis increased 15% during El Niño, but decreased by 12% during La Niña (Cárdenas *et al.*, 2006). Further analysis in a broader area of Colombia has shown mixed results, with some areas showing an increase of incidence during La Niña. A study of the 2003 outbreak of CL in Colombia, the largest ever, found that land use, elevation and climatic variables (mean temperature and precipitation) were statistically significant predictors (Valderrama-Ardila *et al.*, 2010).

The correlation between positive anomalies in sea surface temperatures associated with El Niño and cholera in Peru, Ecuador, Colombia, Mexico and Venezuela is well documented (Moreno, 2006; Gavilán and Martínez-Urtaza, 2011).

Modelling studies about future changes in the geographical distribution of animal reservoirs of viral diseases have been developed for some Latin American countries. This is the case of rodent species in Argentina that harbour the hantavirus pulmonary syndrome virus, which are expected to change their distribution in response to different climate change scenarios. In Patagonia (southern Argentina), climate change may lower the transmission risk by reducing the potential distribution of the reservoir (Carbajo *et al.*, 2009).

18.4 Vulnerability

Global health is committed to promoting better health for all, but focuses on the most vulnerable populations (Feldbaum *et al.*, 2006; Fried *et al.*, 2010). In Latin American countries, issues related to the vulnerability and adaptation of the health sector comprise part of the agenda of regional inter-American and intergovernmental organizations, such as the Inter-American Development Bank (IDB) and the PAHO (PAHO, 2011). The IDB 'Integrated Strategy for Climate Change Adaptation and Mitigation, and Sustainable Renewable Energy' seeks to promote the development and use of public and private instruments to strengthen the capacity of countries to address climate change challenges. Priority sectors for support include sanitation, water resources and disaster risk management, especially through vulnerability assessments of geographical areas and improved methods for risk reduction (IDB, 2011).

During the past decade, several studies in Brazil have examined the social, environmental and health vulnerability to the impacts of climate change (Confalonieri *et al.*, 2009, 2013; Barata *et al.*, 2011). These studies have introduced and quantified composite vulnerability indices at national, regional and local levels, using diverse indicators of population health, socio-economic information and environmental data, in combination with diverse downscaled climatic scenarios. Nationally, the most vulnerable region was the semi-arid north-east, characterized by low socio-economic development and high rates of endemic (neglected) infectious diseases (Confalonieri *et al.*, 2009).

In Colombia, a pilot adaptation strategy is being implemented by the Ministry of Health and National Institute of Health in such a way that the Epidemiological Surveillance System responds to changes in the dynamics of malaria transmission and exposure brought about by climate variability and climate change (Poveda *et al.*, 2011).

Bolivia has developed the National Climate Change Mechanism, which includes strategies for health vulnerability and adaptation assessment. It is being implemented at different administrative levels to reduce climate change health impacts (Arana *et al.*, 2007a).

18.5 Conclusions

Many health outcomes – besides infectious diseases and accidents – are being impacted by climate change and climate variability in LA. These include outcomes associated with nutrition, occupational health (heat strain and heatstroke), respiratory diseases resulting from poor air quality, mental health, skin cancers and diseases associated with environmental pollutants and allergens.

The inhabitants of the Caribbean and Central America, including Colombia and Venezuela, are subject to higher vulnerability from tropical storms and to more intense hurricanes. Populations living in intra-Andean valleys are more vulnerable to intense storms, triggering landslides and large floods. Inhabitants of the low hot and humid regions of the tropical Americas are more vulnerable to climate-sensitive infectious diseases, including malaria, dengue, yellow fever and leishmaniasis. Climate change favours the transmission of those diseases at higher altitudes. In the tropical Americas, human populations are often living with temperatures that are close to intolerable thresholds.

The vulnerability of Central and South American population to the impacts of climate variability and change is well recognized (Moreno, 2006). Many factors contribute to this, including urbanization patterns, poverty, institutional and cultural aspects, poor sanitation and lack of access to clean water (Rodriguez-Morales *et al.*, 2010). Additionally, ecosystem degradation and decline of life-support systems will affect human health and well-being.

Mega- and large cities in LA are particularly vulnerable to climate and global change. Provision of potable water and energy is exacerbated by air and water pollution, and periodic inundations (Borsdorf and Coy, 2004). Increasing levels of social fragmentation and inequality in Latin American countries can exacerbate these problems.

Most Latin American countries have national plans of adaptation to the impacts of global climate change, which usually involve different sectors. Health protection measures are starting to be organized. The PAHO is committed to supporting countries in the development of adaptation plans that promote health protection strategies (PAHO, 2012). Global climate change is one among other recent global crises – economic, food and energy – that make health efforts more challenging, both worldwide and in LA (Beaglehole and Bonita, 2010).

References

Aparicio, M. and Ortiz, P. (2000) *Vulnerabilidad y adaptación de la salud humana ante los efectos del cambio climático en Bolivia*. MDSP-VMARNDF, PNCC PNUD, OPS/OMS – GEF 2000, La Paz, Bolivia.

Aparicio, M., García, J., Aparicio, J., Ríos, N. and Ocampo, M. (2010) El Dengue, el cambio climático y la variabilidad climática en Santa Cruz de la Sierra. *Revista del Colegio Médico de Bolivia* 2.

Aparicio, M., Aparicio, J., Ríos, N., Ocampo, M., Arana, I. and Vargas, J. (2013a) *Agua, cambio climático y salud en Ancoraimes*. IDH IBBA-Universidad Mayor de San Andres, La Paz, Bolivia.

Aparicio, M., Olmos, C., Aparicio, J., Ocampo, M., Pasten, M. and Giménez, A. (2013b) *Climate Health Vulnerability for Extreme Events and Water Sanitation in La Paz – Bolivia*. PAHO WHO, Kobe Center, Japan.

Arana, I., Garcia, M. and Aparicio, M. (2007a) *El cambio climático en Bolivia (análisis, síntesis de impactos y adaptación)*. PNCC,VMPTA-MPD, La Paz, Bolivia.

Arana, I., Garcia, M., Aparicio, M. and Cabrera, M. (2007b) *Mecanismo nacional de adaptación al cambio climático*. Ministerio de Planificación del Desarrollo, VPTA, PNCC, La Paz, Bolivia.

Arboleda, S., Jaramillo-O., N. and Peterson, A.T. (2009) Mapping environmental dimensions of dengue fever transmission risk in the Aburrá valley, Colombia. *International Journal of Environmental Research and Public Health* 6, 3040–3055.

Barata, M., Confalonieri, U., Lima, A., de Lima, A.C.L., Marinho, D.P., Luigi, G., *et al.* (2011) Mapa de vulnerabilidade da população do estado do Rio de Janeiro aos impactos das mudanças climáticas nas áreas social, saúde e ambiente. Secretaria do Ambiente, Rio de Janeiro (http://download.rj.gov.br/documentos/10112/364217/DLFE-40943.pdf/rel_vulbilidade.pdf, accessed 19 April 2012).

Barrios, R.E., Stansbury, J.P., Palencia, R. and Medina, M.T. (2000) Nutritional status of children under 5 years of age in three hurricane-affected areas of Honduras. *Revista Panamericana de Salud Pública* 8, 380–384.

Beaglehole, R. and Bonita, R. (2010) What is global health? *Global Health Action* 3, 5142, doi:10.3402/gha.v3i0.5142.

Borsdorf, A. and Coy, M. (2004) Megacities and global change: case studies from Latin America. *Die Erde* 140, 1–20.

Brazil (2012) *Atlas Brasileiro de desastres naturais 1991–2010.* Volume Brasil. CEPED-UFSC, Florianopólis, Brazil.

Carbajo, A.E., Vera, C. and González, P.L. (2009) Hantavirus reservoir *Oligoryzomys longicaudatus* spatial distribution sensitivity to climate change scenarios in Argentine Patagonia. *International Journal of Health Geographics* 8, 44, doi:10.1186/1476-072X-8-44.

Carbajo, A.E., Cardo, M.V. and Vezzani, D. (2012) Is temperature the main cause of dengue rise in non-endemic countries? The case of Argentina. *International Journal of Health Geographics* 11, 26, doi:10.1186/1476-072X-11-26.

Cárdenas, R., Sandoval, C.M., Rodríguez-Morales, A.J. and Franco-Paredes, C. (2006) Impact of climate variability in the occurrence of leishmaniasis in northeastern Colombia. *American Journal of Tropical Medicine and Hygiene* 75, 273–277.

CEPAL (2007) *Alteraciones Climáticas en Bolivia: Impactos Observados en el Primer Trimestre de 2007* (http://www.eclac.org/publicaciones/xml/4/29494/L792-1.pdf, accessed 10 August 2012).

Checkley, W., Epstein, L.D., Gilman, R.H., Figueroa, D., Cama, R.I., Patz, J.A., *et al.* (2000) Effects of El Niño and ambient temperature on hospital admissions for diarrhoeal diseases in Peruvian children. *The Lancet* 355, 442–450.

Confalonieri, U.E.C., Marinho, D.P. and Rodriguez, R.E. (2009) Public health vulnerability, to climate change in Brazil. *Climate Research* 40, 175–186.

Confalonieri, U.E.C., Lima, A.C.L., Brito, I. and Quintão, A.F. (2013) Social, environmental and health vulnerability to climate change in the Brazilian northeastern region. *Climate Change* doi:10.1007/s10584-013-0811-7.

CRED (Centre for Research on the Epidemiology of Disasters) (2011) *Annual Disaster Statistical Review. The Numbers and Trends*. UC Louvain, Brussels.

Feldbaum, H., Patel, P., Sondorp, E. and Lee, K. (2006) Global health and national security: the need for critical engagement. *Medicine, Conflict and Survival* 22, 192–198.

Fried, L.P., Bentley, M.E., Buekens, P., Burke, D.S., Frenk, J.J., Klag, M.J., *et al.* (2010) Global health is public health. *The Lancet* 375, 535–537.

Gavilán, R.G. and Martínez-Urtaza, J. (2011) Environmental drivers of emergence and spreading of vibrio epidemics in South America. *Revista Peruana de Medicina Experimental y Salud Pública* 28, 109–115.

Gomez, C., Rodríguez-Morales, A.J. and Franco-Paredes, C. (2006) Impact of climate variability in the occurrence of leishmaniasis in Bolivia. *American Journal of Tropical Medicine and Hygiene* 75, 273–277.

IDB (2011) IDB *Integrated Strategy for Climate Change Adaptation and Migration, and Sustainable Renewable Energy*. Inter-American Development Bank, Washington, DC.

Koplan, J.P., Bond, T.C., Merson, M.H., Reddy, K.S., Rodriguez, M.H., Sewankambo, N.K., *et al.* and for the Consortium of Universities for Global Health Executive Board (2009) Towards a common definition of global health. *The Lancet* 373, 1993–1995.

Magrin, G., Marengo, J., Boulanger, J.-P., Buckeridge, M.S., Castellanos, E., Poveda, G., *et al.* (2014) Latin America. In: Barros, V., Field, C.B., Dokken, D.J., Mastrandrea, M.D., Mach, K.J., *et al.* (eds) *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Volume II: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press, Cambridge, UK and New York.

Mangal, T.D., Paterson, S. and Fenton, A. (2008) Predicting the impact of long-term temperature changes on the epidemiology and control of schistosomiasis: a mechanistic model. *PLoS One* 3, 1438–1441.

Mas-Coma, S., Valero, M.A. and Bargues, M.D. (2009) Climate change effects on trematodiases, with emphasis on zoonotic fascioliasis and schistosomiasis. *Veterinary Parasitology* 163, 264–280.

Mena, N., Troyo, A., Bonilla-Carrión, R. and Calderón-Arguedas, Ó. (2011) Factors associated with incidence of dengue in Costa Rica. *Revista Panamericana de Salud Pública* 29, 234–242.

Moreno, A.R. (2006) Climate change and human health in Latin America: drivers, effects, and policies. *Regional Environmental Change* 3, 157–164.

Olson, S.H., Gangnon, R., Elguero, E., Durieux, L., Guégan, J.-F., Foley, J.A., *et al.* (2009) Links between climate, malaria, and wetlands in the Amazon Basin. *Emerging Infectious Diseases* 15, 659–662.

Osorio, L., Todd, J., Pearce, R. and Bradley, D.J. (2007) The role of imported cases in the epidemiology of urban *Plasmodium falciparum* malaria in Quibdó, Colombia. *Tropical Medicine and International Health* 12, 331–341.

PAHO (Pan American Health Organization) (2011) Health situation in the Americas – basic indicators (http://ais.paho.org/chi/brochures/2011/BI_2011_ENG.pdf, accessed 20 August 2012).

PAHO (2012) *Protecting Health from Climate Change*. PAHO, Washington, DC (http://www.who.int/globalchange/publications/Final_Climate_Change.pdf, accessed 20 August 2012).

Pinault, L.L. and Hunter, F.F. (2012) Malaria in highlands of Ecuador since 1900. *Emerging Infectious Diseases* 18, 615–622.

PNUMA (Programa de las Naciones Unidas para el Medio Ambiente), CEPAL and GRID-Arendal (2010) Gráficos vitales del cambo climático para América Latina y el Caribe. PNUMA/CEPAL, Panamá city/Santiago.

Poveda, G., Álvarez, D.M. & Rueda, Ó.A. (2011a) Hydro-climatic variability over the Andes of Colombia associated with ENSO: a review of climatic processes and their impact on one of the Earth's most important biodiversity hotspots. *Climate Dynamics* 36, 2233–2249.

Poveda, G., Estrada-Restrepo, Ó.A., Morales, J.E., Hernandez, O.O., Galeano, A. and Osorio, S. (2011b) Integrating knowledge and management regarding the climate-malaria linkages in Colombia. *Current Opinion in Environmental Sustainability* 3, 448–460.

Riojas-Rodriguez, H., Romero, M.F. and Capítulo, X. (2010) El deterioro de los ecosistemas y la biodiversidad: sus implicaciones en la salud humana. In: Galvão, L.A.C., Finkelman, J. and Henao, S. (eds) *Determinantes Sociales y Ambientales de la Salud Humana*. Organizaciòn Panamericana de la Salud. McGraw-Hill, Washington, DC, pp. 233–258.

Riojas-Rodríguez, H., Hurtado-Diaz, M., Moreno-Banda, G.L., Castañeda-Martínez, A., Saavedra-Lara, N. and Moreno-López, G. (2012) Atlas de Cambio Climático y Salud Humana. México. Instituto Nacional de Salud Pública (http://atlas.insp.mx, accessed 27 August 2012).

Rocha, M.A.G. (2012) Associação espacial entre mortalidade infantil e precipitação pluviométrica no Estado de Pernambuco. Tese de Doutorado. Faculdade de Saúde Pública da Universidade de São Paulo, São Paulo, Brazil.

Rodriguez-Morales, A.J., Risquez, A. and Echezuria, Z. (2010) Impact of climate change on health and disease in Latin America. In: Simar, S. and Austin, M.E. (eds) *Climate Change and Variability*. SCIYO, Rijeka, Croatia, pp. 463–486.

Ruiz, D., Poveda, G. and Vélez, I.D. (2006) Modelling entomological–climatic interactions of *Plasmodium falciparum* malaria transmission in two Colombian endemic-regions: contributions to a national malaria early warning system. *Malaria Journal* 1, 66, doi: 10.1186/1475-2875-5-66.

Rutar, T., Salgueiro, E. and Maguire, J. (2004) Introduced *Plasmodium vivax* malaria in a Bolivian community at an elevation of 2,300 meters. *American Journal of Tropical Medicine and Hygiene* 70, 15–19.

Salomón, O.D., Quintana, M.G., Mastrángel, A.V. and Fernández, M.S. (2012) Leishmaniasis and climate change-case study: Argentina. *Journal of Tropical Medicine* 601242, doi:10.1155/2012/601242.

Shephard, D.S., Coudeville, L., Halas, Y.A., Zambrano, B. and Dayan, G.H. (2011) Economic impact of dengue illness in the Americas. *American Journal of Tropical Medicine and Hygiene* 84, 200–207.

Team, V. and Manderson, L. (2011) Social and public health effects of climate change in the '40 south'. *Wiley Interdisciplinary Reviews: Climate Change* 2, 902–918.

UN Habitat (2012) *Estado de las ciudades de América Latina y el Caribe 2012. Rumbo a una nueva transición urbana*. Nairobi.

Valderrama-Ardila, C., Alexander, N., Ferro, C., Cadena, H., Marín, D., Holford, T.R., *et al.* (2010) Environmental risk factors for the incidence of American cutaneous leishmaniasis in a sub-Andean zone of Colombia (Chaparral, Tolima). *American Journal of Tropical Medicine and Hygiene* 82, 243–250.

Wolfhart, B.R. (2011) Análise epidemiológica, espacial e temporal e suas relações com as variáveis ambientais sobre a incidência da malária no período 2003 a 2009 em 4 municípios do Estado do Amazonas, Brasil. Dissertação (Mestrado), INPA, Manaus, Brazil.