



Review of Tools for Climate Change and Infectious Diseases Web System Development

Health Analysis & Information For Action (HAIFA)

Anke Timmermann

ISBN 978-1-877166-25-9 June 2012



Acknowledgements

The author would like to thank David Slaney for peer review.

This work was funded by the New Zealand Foundation for Research, Science and Technology and the Ministry of Science and Innovation (contract C03X0801).

Front cover images:

New Zealand and cyclone images were sourced from <http://www.nasa.gov>

The drought, flood and crowd images were sourced from <http://www.istockphoto.com>

Disclaimer

This report or document ("the Report") was prepared by the Institute of Environmental Science and Research Limited ("ESR") for the benefit of ESR. Neither ESR nor any of its employees makes any warranty, express or implied, or assumes any legal liability or responsibility for use of the Report or its contents by any other person or organisation.

ISBN 978-1-877166-25-9 (PDF)

Published by
Environmental Science and Research Limited
P O Box 50-348
Porirua 5240
New Zealand

<http://www.esr.cri.nz>

Copyright © ESR 2012

Table of Contents

1.	Review of Tools for HAIFA Web System Development	1
1.1	MIASMA	1
1.2	CIMSIM and DENSIM	3
1.3	HOTSPOTS	4
1.4	MARA and MARA LITE	6
1.5	Mapping the future	8
1.6	TARGETS	10
1.7	Google earth tools	11
1.8	Additional tools reviewed	12
	References	13

1. Review of Tools for HAIFA Web System Development

In 2009/10 a review exercise revealed that there are a wide range of papers published and models developed concerning the impacts of climate variability and change on human health and infectious diseases world wide (e.g. Hunter 2003; Kovats *et al.* 2003; Nakhapakorn and Tripathi 2005; Patrick *et al.* 2004; Lindsay *et al.* 2002; Jetten and Focks 1997). A few of these use Geographic Information System (GIS) functionalities for spatial analysis processes (e.g. Kolivras 2006; Depradine and Lovell 2004; Gatton *et al.* 2004; Patz and Balbus 1996; de Wet *et al.* 2005a,b). The review also revealed that there are both online tools that allow users to create images, maps and even videos of how the climate may change (e.g. ClimateWizard, SERVIR-Viz) and online ones for health and disease surveillance (e.g. HealthMap, WHO's Communicable Disease Global Atlas including DengueNet and FluNet). However, no web based tools incorporating models of human infectious disease and future climate change scenarios could be found.

Nevertheless, offline standalone human health tools suited to examining impacts of climate change on human diseases have been developed. Following is a summary of those tools reviewed at the time of writing.

1.1 MIASMA

The MIASMA (Modelling Framework for the Health Impact Assessment of Man-Induced Atmospheric Changes) consists of several models built to investigate the impacts of global climate change on thermal heat mortality, UV-related skin cancer and three vector-borne diseases (malaria, dengue fever and schistosomiasis). The models are driven by scenarios of population estimates and atmospheric changes, superimposed on baseline data regarding disease incidence, climatic conditions, and ozone-layer thickness (Martens 1996).

	MIASMA (Modelling Framework for the Health Impact Assessment of Man-Induced Atmospheric Changes)
Source of data	
• Organisation	National Institute of Public Health and Environmental Protection (RIVM) in the Netherlands
• Contact person	Pim Martens, ICIS, PO Box 616, 6200 Maastricht, The Netherlands
Primary purpose	<ul style="list-style-type: none"> • Describes the major cause and effect relationship between atmospheric changes and human population health. • Set of 5 modules simulating thermal stress induced mortality in 20 cities, skin cancer changes in Netherlands/Australia, and changes in populations at risk to three major vector borne diseases (malaria, schistosomiasis and dengue) in various areas as a result of climate changes.
Geographic and data coverage	<ul style="list-style-type: none"> • Vector-borne disease module has been used globally, malaria module in Zimbabwe, and dengue module for Bangkok, San Juan, Mexico City, Athens and Philadelphia.
Time period covered	<ul style="list-style-type: none"> • 1970 – 2100, running in time steps of one year.
System background and data collection (including visual tools)	<ul style="list-style-type: none"> • The models are driven by scenarios of population figures and atmospheric changes, superimposed on baseline data regarding disease incidence, climatic conditions, and ozone-layer thickness. • In the vector-borne disease model, the dynamics of malaria, schistosomiasis, and dengue are simulated in relation to climate changes. Relationships between temperature, precipitation, and vector characteristics are based on a variety of field and laboratory data.

<p>System background and data collection (including visual tools)</p>	<ul style="list-style-type: none"> • To represent a wide range of climatic conditions and levels of socio-economic developments, effects of thermal stress on cardiovascular, respiratory, and total mortality have been simulated for 20 cities throughout the world. The association between winter and summer temperatures and mortality rates has been estimated by means of a meta-analysis, aggregating the results of several epidemiological studies on the subject. Projections of future risks are then simulated by simple extrapolation of this calculated relationship. Effects of acclimatisation to increasing temperatures, physiological as well as technological, are simulated. • Developed in MyM, which provides a basic set of tools that allow model builders from various backgrounds, policy analysts, interface designers and visualisation experts to work together within a shared environment.
--	---

Related Publications

Martens WJM. 1996. Global atmospheric change and human health: an integrated modelling approach. *Climatic Research* 6:107-112.

Martens WJM. 1998. Climate change, thermal stress and mortality changes. *Soc. Sci. Med.* 46(3):331-344.

Martens P. 1998. Health and Climate Change: Modelling the Impacts of Global Warming and Ozone Depletion. *Earthscan Publications*, London.

Martens WJM, Jetten TH, Rotmans J, and Niessen LW. 1995. Climate change and vector-borne diseases: A global modelling perspective. *Global Environmental Change* 5(3):195-209.

Martens WJM, Jetten TH, and FocksDA. 1997. Sensitivity of malaria, schistosomiasis, and dengue to global warming. *Climatic Change* 35:145-156.

1.2 CIMSiM and DENSiM

A Container Inhabiting Mosquito Simulation Model (CIMSiM) has been developed together with a Dengue Simulation Model (DENSiM) in order to describe the daily dynamics of dengue virus transmission in the urban environment (Focks *et al.* 1995). The results of CIMSiM, a weather driven dynamic life-table simulation model of container-inhabiting mosquitoes, serve as the inputs for DENSiM. Human population growth in response to country and age specific birth and death rates are simulated and form the basis of the dengue transmission model.

	CIMSiM (Container Inhabiting Mosquito Simulation Model) and DENSiM (Dengue Simulation Model)
Source of data	
• Organisation	Infectious Disease Analysis, Gainesville, Florida
• Contact person	Dana A. Focks, Infectious Disease Analysis, PO Box 12852, Gainesville, Florida 32604, USA
Primary purpose	<ul style="list-style-type: none"> • The pair of stochastic simulation models estimates mosquito density and survival as well as the prevalence and incidence of dengue in a human population according to site-specific variables such as microclimate. It describes the daily dynamics of dengue virus transmission in an urban environment. • Main use to <ul style="list-style-type: none"> - optimise dengue control strategies using multiple control measures. - develop transmission thresholds in terms of <i>Ae. aegypti</i> pupae per person as a function of temperature and herd immunity. - evaluate the impact of climate change.
Geographic and data coverage	<ul style="list-style-type: none"> • Pupal/ demographic survey data to estimate the productivities of the various local water-holding containers. • Daily weather data → maximum/ minimum temperature, rainfall, and saturation deficit.
Time period covered	• Present
System background and data collection (including visual tools)	<ul style="list-style-type: none"> • CIMSiM- Container Inhabiting Mosquito Simulation Model <ul style="list-style-type: none"> - Population dynamics model of vector, life history, mechanistic. - Weather-driven and site-specific parameterisation, daily resolution. • DENSiM- Dengue Simulation Model <ul style="list-style-type: none"> - Population dynamics model of host, daily resolution. - Weather-driven and a function of vectors, demographics, nature of virus, herd immunity, etc. - Uses output of CIMSiM for vector population for transmission dynamics.

Related Publications

Focks DA. 2003. A Review of Entomological Sampling Methods and Indicators for Dengue Vectors. Tropical Disease Research, World Health Organization, Geneva.

Focks DA, Haile DG, Daniels E, and Mount GA. 1993. Dynamic life table model for *Aedes aegypti* (Diptera: Culicidae): analysis of the literature and model development. *J. Med. Entomol.* 30(6):1003-17.

Focks DA, Haile DG, Daniels E, and Mount GA. 1993. Dynamic life table model for *Aedes aegypti* (diptera: Culicidae): simulation results and validation. *J. Med. Entomol.* 30(6):1018-28.

Focks DA, Daniels E, Haile DG, and Keesling JE. 1995. A simulation model of the epidemiology of urban dengue fever: literature analysis, model development, preliminary validation, and samples of simulation results. *Am. J. Trop. Med. Hyg.* 53(5):489-506.

Focks DA, Brenner RJ, Hayes J, and Daniels E. 2000. Transmission thresholds for dengue in terms of *Aedes aegypti* pupae per person with discussion of their utility in source reduction efforts. *Am. J. Trop. Med. Hyg.* 62(1):11-18.

Jetten TH, and Focks DA. 1997. Changes in the distribution of dengue transmission under climate warming scenarios. *Am. J. Trop. Med. Hyg.* 57:285-297.

1.3 HOTSPOTS

The simulation tool Hotspots identifies potential distributions for seven exotic vector mosquitoes in New Zealand under present climatic conditions and projected scenarios of climate change (de Wet *et al.* 2005a,b). Hotspots is a GIS that integrates data and models for mosquito biology, mosquito distributions, climate, land cover, topography, human demography and international trade and travel patterns.

	HOTSPOTS
Source of data	
• Organisation	International Global Change Institute (IGCI), University of Waikato, Hamilton, and the Ecology and Health Research Centre, University of Otago, Wellington
• Contact person	igci@waikato.ac.nz
Primary purpose	<ul style="list-style-type: none"> • The Hotspots computer model is a mosquito-borne disease risk assessment and risk management decision support tool for New Zealand. • It provides a useful decision support tool that helps investigate and answer questions of policy, scientific and operational relevance.
Geographic and data coverage	<ul style="list-style-type: none"> • MAGICC library files → Global mean temperature change projections using MAGICC model output • Global climatology • Country climatology • Regional (local) climatology • GHG emission scenarios • DARLAM GCM pattern • Country ENSO pattern • Regional ENSO pattern • Vector bionomic data • Land cover data • Total imports • Used tyre import • Passenger arrival • Urban Population • Population density • NZDPI • Global vector distributions
Time period covered	<ul style="list-style-type: none"> • Present and future scenarios

<p>System background and data collection (including visual tools)</p>	<ul style="list-style-type: none"> • The Hotspots system includes a purpose-built geographical information system (GIS), a user-friendly graphic user interface (GUI), and data compression and storage routines. • Models and data are integrated in a way that facilitates rapid generation of a range of scenarios that support spatial analysis of potential distributions of mosquitoes and of arboviral risks in New Zealand. • The design of the Hotspots system is structured around three scales or modes of operation - each of which recruits a different combination of the available sub-models, employs different datasets, as appropriate to scale and function, and supports analysis useful for different purposes. These three modes are designated as: <ol style="list-style-type: none"> 1. Global scale mode – providing a global window; 2. NZ Country scale mode – providing windows of the North Island or South Island of New Zealand; 3. Regional scale mode – providing windows at the sub-national or local level for regions as designated by Regional Council boundaries. • Key components: <ul style="list-style-type: none"> - MAGICC → a simple global climate model - Climate scenario generator - Vector distribution model – climatic suitability - Vector distribution model – habitat suitability - Demographic risk model - Vector introduction risk model - Virus introduction risk model - Hotspots identifier - Transmission model
--	--

Related Publications

de Wet N, Ye W, Hales S, Warrick R, Woodward A, and Weinstein P. 2001. Use of a computer model to identify potential hotspots for dengue fever in New Zealand. *NZMJ* 114 (1140):420-2.

de Wet N, Slaney D, Ye W, Warrick R, and Hales S. 2005. Hotspots: Exotic mosquito risk profiles for New Zealand. International Global Change Institute, University of Waikato, Hamilton and Ecology and Health Research Centre, Wellington School of Medicine and Health Sciences, University of Otago, Wellington.

de Wet N, Slaney D, Ye W, Warrick R, and Hales S. 2005. Hotspots – capacity for the analysis of mosquito-borne disease risks in New Zealand. A case study of *Ochlerotatus camptorhynchus* incursions in New Zealand. International Global Change Institute, University of Waikato, Hamilton and Ecology and Health Research Centre, Wellington School of Medicine and Health Sciences, University of Otago, Wellington.

de Wet N, Ye W, Slaney D, Hales S, and Warrick R. 2005. *Hotspots – capacity for the analysis of mosquito-borne disease risks in New Zealand. System description and users' guide*. International Global Change Institute, University of Waikato, Hamilton and Ecology and Health Research Centre, Wellington School of Medicine and Health Sciences, University of Otago, Wellington.

1.4 MARA and MARA LITe

MARA (Mapping Malaria Risk in Africa) is a biological model built to determine any geographic location's suitability to Malaria distribution (www.mara.org.za). A stand-alone data viewing and query system for the MARA database is provided by MARA Lite. MARA is implemented in GIS format (MapInfo). Work done in the frame of the MARA collaboration has allowed the systematic analysis of malaria epidemiology at the continental level. The MARA operational model and database structure are being applied in mapping malaria in South East Asia and can be adapted for similar efforts elsewhere.

	MARA (Mapping Malaria Risk in Africa) and MARA LITe (Low-end Information Tool)
Source of data	
• Organisation	International collaboration
• Contact person	South African Medical Research Council, PO Box 17120, Congella, Durban 4013, South Africa
Primary purpose	<ul style="list-style-type: none"> • To carry out a comprehensive collection of available malaria data for the African continent. • To highlight areas of no or sparse data. • To spatially define factors which exclude malaria (eg. absence of population, high altitude, deserts) in order to delineate zones where malaria transmission is unlikely to occur. • To define malaria risk categories in terms of climatic and environmental data and to develop models able to predict malaria risk over the whole continent. • To map areas at risk of epidemic malaria. • To develop a base-map of malaria risk in Africa, at the level of second administrative unit ("district") which integrate geographic, population and environmental factors. • To make continental and national risk maps available to national, regional and international organisations. • MARA LITe serves as a data viewing and query software package to make the prevalence and population at risk information on country, province or district level more assessable to end users. • Projections of possible populations at risk and future prevalence of malaria for a given region can be made in conjunction with climate change scenarios in MARA LITe.
Geographic and data coverage	<ul style="list-style-type: none"> • Empirical Data Collection: <ul style="list-style-type: none"> - Parasite ratio → the percentage of people examined carrying malaria - Incidence data → number of people affected with malaria over a specific period of time - Entomological inoculation rates → number of infective mosquito bites per person over a specific period of time • Geographical modelling data: <ul style="list-style-type: none"> - Mean monthly rainfall for the continent (resolution: 5 x 5 km) - Mean monthly minimum and maximum temperature (resolution: 5 x 5 km) - Elevation - Vegetation Index (Amount of vegetation) - Vegetation Classification (Types of vegetation) • Mosquito distribution → derived from malaria vector surveys • Population

Time period covered	<ul style="list-style-type: none"> • Present and future scenarios
System background and data collection (including visual tools)	<ul style="list-style-type: none"> • Empirical data sources: <ul style="list-style-type: none"> - Journal articles - Personal correspondence with authors - Health departments - Books, reports, theses, etc. • Decision rules were developed using fuzzy logic to resolve the uncertainty in defining distinct boundaries dividing malarious from nonmalarious regions. • Predictive geographical modelling of malaria on the basis of climatic and other environmental factors using GIS as well as spatial statistical approaches. • Further modelling is addressing issues of malaria seasonality, the frequency of epidemics in fringe areas, and, at a smaller scale, a description of malaria endemicity and levels of transmission intensity, based on both empirical and environmental data.

Related Publications

Craig MH, Snow RW, and le Sueur D. 1999. A climate-based distribution model of malaria transmission in sub-Saharan Africa. *Parasitol. Today* 15(3):105-11.

Kleinschmidt I, Bagayoko M, Clarke GP, Craig M, and Le Sueur D. 2000. A spatial statistical approach to malaria mapping. *Int. J. Epidemiol.* 29(2):355-61.

Omumbo J, Ouma J, Rapuoda B, Craig MH, le Sueur D, and Snow RW. 1998. Mapping malaria transmission intensity using geographical information systems (GIS): an example from Kenya. *Ann. Trop. Med. Parasitol.* 92(1):7-21.

Snow RW, Gouws E, Omumbo J, Rapuoda B, Craig MH, Tanser FC, le Sueur D, and Ouma J. 1998. Models to predict the intensity of Plasmodium falciparum transmission: applications to the burden of disease in Kenya. *Trans. R. Soc. Trop. Med. Hyg.* 92(6):601-6.

Snow RW, Craig MH, Deichmann U, and le Sueur D. 1999. A preliminary continental risk map for malaria mortality among African children. *Parasitol. Today* 15(3):99-104.

1.5 Mapping the Future

'Mapping the Future' is a simulation tool which, among other model components, contains climate change scenario models (www.creatingfutures.org.nz). This spatial decision support system (SDSS) that evaluates, deliberates and creates futures through scenario analysis and multi-criteria evaluation frameworks at different levels in the Waikato region was developed by Waikato Regional Council in collaboration with other research institutes. The purpose of this tool is to support long-term integrated planning for Waikato by integrating a series of simulation models running on an annual time step from 2006 to 2050.

	Mapping the Future - Spatial Waikato Model
Source of data	
• Organisation	Waikato Regional Council and collaborating organisations
• Contact person	Beat Huser, Waikato Regional Council, Private Bag 3038, Waikato Mail Centre, Hamilton 3240, New Zealand
Primary purpose	<ul style="list-style-type: none"> • A spatial decision support system (SDSS) to support the evaluation and deliberation processes for trade-offs between economic, environmental and social/cultural outcomes and the cumulative effects of many decisions over space and time. • To support long-term integrated planning for Waikato by evaluating, deliberating and creating futures through scenario analysis and multi-criteria evaluation frameworks.
Geographic and data coverage	<ul style="list-style-type: none"> • Landuse Model • Demographics Model • Climate Change Scenario Models • Hydrology Model • Waikato Region Dynamic Economy-Environment Model • Water Quality Model • Dairying Model • Terrestrial Biodiversity Model
Time period covered	<ul style="list-style-type: none"> • 2006 - 2050
System background and data collection (including visual tools)	<ul style="list-style-type: none"> • The overall system design of the Choosing Regional Futures SDSS consists of a series of integrated model components that operate at four spatial scales: NZ & the World, the Waikato region, districts (e.g. Waipa, Matamata-Piako), and local i.e. 200m x 200m grid cells • New Zealand to Global Scale <ul style="list-style-type: none"> - Climate Change Scenarios – consist of standard IPCC climate change scenarios down-scaled for use at scales relevant to New Zealand. - External Drivers – consist of key factors that may strongly influence New Zealand and/or the Waikato region, such as foreign exchange rates, world commodity prices, interest rates, credit availability, migration trends, technological developments, etc. • Regional Scale <ul style="list-style-type: none"> - Waikato Region Dynamic Economy-Environment Model (WRDEEM) – a system dynamics model of region-wide environment-economy interactions adapted from a model developed for Auckland. WRDEEM consists of six sub-modules: Population, Labour Force, Growth, Economics, Economic Physical Flow, and Environment-Economic Physical Flow. It models the flow of economic commodities as traded on markets in both monetary and physical terms (tonnes), along with the flow of associated natural resource inputs (e.g. land, energy, water) and residual outputs (e.g. wastes, pollutants and emissions). The model simulates the combined environmental and economic implications of economic change in the Waikato Region between 2006 and 2050. The model is driven by scenarios of economic growth.

<p>System background and data collection (including visual tools)</p>	<ul style="list-style-type: none"> - Hydrology – consists of the TOPNET model, which simulates surface and shallow groundwater hydrology to generate hourly time series of river flow and soil moisture. Model simulations can cover periods of several years to decades. TOPNET also includes impacts of spatially-varying climate, soil, vegetation and topography on hydrological response. - Water Quality - represents an adaptation of U.S Geological Survey SPARROW model to New Zealand. SPARROW estimates pollution loads, (e.g., total nitrogen) at selected points in a river network as a function of upstream catchment characteristics including land use. • District Scale <ul style="list-style-type: none"> - Zoning – consists of zoning maps prepared as part of district/city plans. Zoning delineates where different land use activities are or are not permitted. It affects land use change in the local scale (see below) by controlling where different land uses can and cannot occur. - Demographics – consists of the PROJECTIONS model that projects population over time, expressed as 1-year male and female age cohorts. The intent is to run a separate population model for each district which will estimate birth rates, death rates, and net migration rates from each district to other districts within the Waikato region, and from each district to outside the region. - Dairying – will model the effects of dairying intensity aggregated by district based on a combination of physical attributes or suitability, production targets (i.e. kg/milk solids/ha desired), and management practices. • Local Scale <ul style="list-style-type: none"> - Land Use Change - dynamically models land use change over time based on demand for land uses generated at the district or regional scales and a combination of four other factors: zoning, suitability, accessibility, and local influence. Suitability estimates the biophysical suitability of land for different uses. Accessibility typically relates to travel distances, which can affect the desirability of some land uses such as housing. Local influence measures the influence of neighbouring land uses on a land use at a particular point. - Biodiversity – will track changes in indigenous and exotic land cover over time. It combines information on land cover with information on protected areas and land environments to provide information on terrestrial biodiversity status across a range of scales. We are also investigating incorporating information on freshwater biodiversity. - Spatial Indicators – track the status of different model inputs and outputs over time. Indicators would consist of a series of maps depicting indicator change over time. Land use change is an example of a basic indicator that can be generated. The series of maps can be saved as an animated image and use for reporting, communication, and education purposes.
--	--

Related Publications

A range of publications are available covering the project and the tools developed from the Mapping the Future web site www.creatingfutures.org.nz.

1.6 TARGETS

In order to operationalise the concept of sustainable development from a global perspective the integrated assessment model TARGETS (Tool to Assess Regional and Global Environmental and health Targets for Sustainability) has been developed. The purpose of TARGETS is to assess the correlations between social, economic and biophysical processes on a global scale.

	TARGETS (Tool to Assess Regional and Global Environmental and health Targets for Sustainability)
Source of data	
• Organisation	National Institute for Public Health and Environmental Protection and collaborating organisations
• Contact person	Jan Rotmans, National Institute for Public Health and Environmental Protection, PO Box 1, 3720 BA Bilthoven, The Netherlands
Primary purpose	<ul style="list-style-type: none"> • Operationalise the concept of sustainable development from a global perspective. • Assess the interlinkages between social, economic and biophysical processes on a global scale • Experimenting tool rather than a prediction tool. • Aims at producing fresh insights, not ready-made answers, on issues of global change processes in the context of the Rio Declaration on Sustainable Development and Agenda 21.
Geographic and data coverage	<ul style="list-style-type: none"> • Global data regarding population, health, energy, land, water and element cycles
Time period covered	<ul style="list-style-type: none"> • 1900 – 2100, 1 year time steps
System background and data collection (including visual tools)	<ul style="list-style-type: none"> • An integrated systems approach is used to analyse a number of key aspects of global change. • The conceptual framework used consists of two strongly interconnected components: the human and environmental subsystem. Each of them has in turn been split up into subsystems which are all interlinked and related to the economic scenario generator. • The Pressure-State-Impact-Response concept is used as organising principle for achieving a plausible division of the cause-effect chains into subsystems. • The Pressure System represents social, economic and ecological driving forces underlying the pressure on the human and environmental system. • The State System represents physical, chemical and biological changes in the state of the biosphere, as well as changes in human population and resources/capitals. • The Impact System represents social, economic and ecological impacts as a result of human and/or natural disturbance. • The Response System represents human intervention in response to ecological and societal impacts.

Related Publications

Rotmans J, van Asselt MBA, de Bruin AJ, den Elzen MGJ, de Greef J, Hilderink H, Hoekstra AY, Janssen MA, Koster HW, Martens WJM, Niessen LW, and de Vries HJM. 1994. Global Change and Sustainable Development: A Modeling Perspective for the Next Decade. RIVM-Report No. 461502000. Bilthoven, The Netherlands: National Institute of Public Health and Environmental Protection (RIVM). Available from: <http://sedac.ciesin.columbia.edu/mva/JR1994A/JR1994A.html>

Rotmans J, and de Vries HJM (ed.). 1997. Perspective on Global Change: The TARGETS approach. Cambridge University Press.

1.7 Google Earth Tools

FluTrackers is an animated Google Earth file representing projections for the changes in transmission of dengue fever around the world for the time steps 2020, 2050 and 2080 and of malaria in Africa for 2010, 2040, and 2070. The layers in the Google Earth Keyhole Markup Language (KML) file are based on studies undertaken by Hales *et al.* (2002), Ebi *et al.* (2005) and Transer *et al.* (2003). The KML file can be downloaded from www.flutrackers.com/forum/showthread.php?t=64254 and loaded into Google Earth.

Google Earth Outreach provides a portal where non-profit and public benefit organisations can upload their mapping projects. One of those projects found in the Public Health showcase is the **Influenza in Brazil** Google Earth project (www.google.com/gadgets/directory?synd=earth&hl=pt-BR&gl=BR&id=659567794137). This KML file is an animated visualisation of influenza seasonality tool showing the circulation of influenza and pneumonia and mortality from 1997 to 2000 in Brazil. However, this project does not provide a predictive model for future time periods. An additional layer reflecting the change of the monthly mean temperature is included and can be displayed in the background.

Science Progress launched an interactive web map tool **The Human Toll of Climate Change** based on Google maps, where people can add news and research findings to the map (www.maps.scienceprogress.org/climate/). The map geographically shows news and information about impacts of climate change on 15 different categories one of which is 'Consequences for Human Health'. An icon is used to display the location of the problem or potential threat identified by scientific research. Further information about the data along with the data source is provided by clicking on the icon. The information is compiled from a variety of sources. This tool displays where research has been undertaken but provides no simulation capability. Although at this stage the map only shows a limited number of research studies it may be a useful tool to provide an overview of research results concerning the impacts of current and future climate change.

1.8 Additional Tools Reviewed

In addition to the tools described above publications concerning general web services and disease information were found during the review process.

Sauchyn *et al.* (2003) describe an Internet Map Server (IMS) that has been implemented at the PARC (Prairie Adaptation Research Collaborative) website (www.parc.ca). This website serves as a platform for sharing information and encouraging discussion of climate change impacts and adaptation. The IMS is supposed to host the output from climate impact models, such that the model results can be customised by the web site user and be most readily applied to the planning and analysis of adaptation strategies.

Gao *et al.* (2008a, 2008b) developed a framework, based on which a service oriented online disease mapping architecture was designed and implemented. The web application provides exploratory and descriptive analysis of health information, hypothesis-generation, and decision making. It allows quicker access to spatial and health data in understanding the trends in disease, and promotes the growth and enrichment of the spatial data infrastructure in the public sector.

Bernier *et al.* (2009) demonstrated the potential of Spatial On-Line Analytical Processing (SOLAP) tools to support the interactive exploration and analysis of geo-referenced indicators relevant for the monitoring of climate change impacts on population health and wellbeing. For this purpose a spatial-temporal web-based application that supports the multi-scale exploration and analysis of integrated socio-economic, health and environmental geospatial data over several periods is described in Bernier *et al.* (2009).

The potential of combining Google Earth and free GIS software to strengthen overall public health capacity and facilitate decision support system approaches to prevention and control vector-borne diseases in resource-poor environments was shown by Lozano-Fuentes *et al.* (2008). They describe a method of using satellite imagery and feature-making tools provided by Google Earth to develop city infrastructure data layers that can be imported into GIS and form the backbone of a local dengue decision support system.

References

- Bernier E, Gosselin P, Badard T, and Bédard Y. 2009. Easier surveillance of climate- related health vulnerabilities through a Web-based spatial OLAP application. *Int. J. Health Geogr.* 8:18.
- Depradine C, and Lovell E. 2004. Climatological variables and the incidence of Dengue fever in Barbados. *Int. J. Environ. Health Res.* 14(6):429-41.
- de Wet N, Slaney D, Ye W, Warrick R, and Hales S. 2005a. Hotspots: Exotic mosquito risk profiles for New Zealand. International Global Change Institute, University of Waikato, Hamilton and Ecology and Health Research Centre, Wellington School of Medicine and Health Sciences, University of Otago, Wellington.
- de Wet N, Slaney D, Ye W, Warrick R, and Hales S. 2005b. Hotspots – capacity for the analysis of mosquito-borne disease risks in New Zealand. A case study of *Ochlerotatus camptorhynchus* incursions in New Zealand. International Global Change Institute, University of Waikato, Hamilton and Ecology and Health Research Centre, Wellington School of Medicine and Health Sciences, University of Otago, Wellington.
- Ebi KL, Hartman J, Chan N, Mcconnell J, Schlesinger M, and Weyant J. 2005. Climate suitability for stable malaria transmission in Zimbabwe under different climate change scenarios. *Climatic Change* 73(3): 375-393.
- Focks DA, Daniels E, Haile DG, and Keesling JE. 1995. A Simulation model of the epidemiology of urban dengue fever: Literature analysis, model development, preliminary validation, and samples of simulation results. *Am. J. Trop. Med. Hyg.* 53(5):489-506.
- Gao S, Mioc D, Yi X, Anton F, and Oldfield E. 2008a. Geospatial services for decision support on public health. *The International Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences* 37(B8).
- Gao S, Mioc D, Anton F, Yi X, and Coleman DJ. 2008b. Online GIS services for mapping and sharing disease information. *Int. J. Health Geogr.* 7:8.
- Gatton ML, Kelly-Hope LA, Kay BH, and Ryan PA. 2004. Spatial-temporal analysis of Ross River virus disease patterns in Queensland, Australia. *Am. J. Trop. Med. Hyg.* 71(5):629-35.
- Hales S, de Wet N, Maindonald J, and Woodward A. 2002. Potential effect of population and climate changes on global distribution of dengue fever: an empirical model. *Lancet* 360(9336):830-4.
- Hunter PR. 2003. Climate change and waterborne and vector-borne disease. *J. Appl. Microbiol.* 94:375-465.
- Jetten TH, and Focks DA. 1997. Potential Changes in the distribution of dengue transmission under climate warming. *Am. J. Trop. Med. Hyg.* 57(3):285-297.
- Kolivras NK. 2006. Mosquito habitat and dengue risk potential in Hawaii: A conceptual framework and GIS application. *The Professional Geographer* 58(2):139-154.
- Kovats RS, Edwards SJ, Charron D, Cowden J, D'Souza RM, Ebi KL, Gauci C, Gerner-Smidt P, Hajat S, Hales S, Hernández Pezzi G, Kriz B, Kutsar K, McKeown P, Mellou K, Menne B, O'Brien S, van Pelt W, and Schmid H. 2005. Climate variability and campylobacter infection: an international study. *Int. J. Biometeorol.* 49(4):207-14.
- Lindsay AP, Hope V, Marshall RJ, and Salinger J. 2002. Meningococcal disease and meteorological conditions in Auckland, New Zealand. *Aust. NZ. J. Public Health* 26(3):212-8.
- Lozano-Fuentes S, Elizondo-Quiroga D, Farfan-Ale JA, Loroño-Pino MA, Garcia-Rejon J, Gomez-Carro S, Lira-Zumbardo V, Najera-Vazquez R, Fernandez-Salas I, Calderon-Martinez J, Dominguez-Galera M, Mis-Avila P, Morris N, Coleman M, Moore CG, Beaty BJ, and Eisen L. 2008. Use of Google Earth to strengthen public health capacity and facilitate management of vector-borne diseases in resource-poor environments. *Bull. World Health Organ.* 86(9):718-25.

- Martens P. 1996. Global atmospheric change and human health: an integrated modelling approach. *Climate Research* 6:107-112.
- Nakhapakorn K, and Tripathi NK. 2005. An information value based analysis of physical and climatic factors affecting dengue fever and dengue haemorrhagic fever incidence. *Int. J. Health Geogr.* 4:13.
- Patrick ME, Christiansen LE, Wainø M, Ethelberg S, Madsen H, and Wegener HC. 2004. Effects of climate on incidence of *Campylobacter* spp. in humans and prevalence in broiler flocks in Denmark. *Appl. Environ. Microbiol.* 70(12):7474-80.
- Patz A, and Balbus JM. 1996. Methods for assessing public health vulnerability to global climate change. *Climate Research* 6:113-125.
- Tanser FC, Sharp B, and le Sueur D. 2003. Potential effect of climate change on malaria transmission in Africa. *Lancet* 362(9398):1792-8.
- Sauchyn DJ, Joss BN, and Nyirfa WN. 2003. Sharing the geo-referenced results of climate change impact research. *Environ. Monit. Assess.* 88(1-3):389-97.



© 2012