Special report

Pan American Journal of Public Health

An observatory to gather and disseminate information on the health-related effects of environmental and climate change

Christovam Barcellos,[1] *Emmanuel Roux,*[2] *Pietro Ceccato,*[3] *Pierre Gosselin,*[4] *Antonio Miguel Monteiro,*[5] *Vanderlei Pascoal de Matos,*[1] *and Diego Ricardo Xavier*[1]

Suggested citation Barcellos C, Roux E, Cecatto P, Gosselin P, Monteiro AM, de Matos VP, et al. An observatory to gather and disseminate information on the health-related effects of environmental and climate change. Rev Panam Salud Publica. 2016;40(3):167–73.

ABSTRACT *This report sought to critically examine proposals, potentials, and challenges of environmental health observatories with an emphasis on climate change processes. A critical review of existing environmental health observatories was performed, examining their purposes, potential audiences, and technological platforms. The implementation of the Brazilian Climate and Health Observatory (C&HO) is described, and two stages are defined: (i) the requirement analysis and negotiation stage that identified the national and regional institutional players and their roles as data producers/users; and (ii) thematic health-related workshops that reviewed water-related diseases, vector-borne diseases, extreme climate events, and health problems derived from forest fires. The C&HO is an example of making information on climate and health available through an Internet site where data from different origins can be accessed on a common platform. Complex queries are made by users and can be executed over multiple sites, geographically distributed, with all technical details hidden from the end user. At this stage of the C&HO prototype, alongside the queries, users can also produce semi-qualitative graphs and maps. A multi-scale approach was developed using the platform by setting up sentinel sites. Building a successful observatory is a participatory process that involves choosing indicators, data sources, information technology, and languages to best reach different audiences, such as researchers, citizens, public health professionals, and decisionmakers.*

Keywords Climate change; information services; environment and public health; health surveillance; Brazil.

A variety of diseases and health problems may be affected by climate change. Extreme weather events, such as heat waves, hurricanes, storms, and floods, have a direct impact on the health and well being of the population. However, their impact is mostly indirect and mediated by environmental processes, such as changes to ecosystems, biodiversity, land use, and biogeochemical cycles (1). Health impacts of meteorological and climatic events are also mediated by societal factors that may reduce or amplify vulnerabilities of population groups (2) according to the differential appropriation of natural resources by and among a society (3). In this sense, vulnerability is determined by the capacity of individuals, groups, and communities to respond to potential dangers triggered by events related to environmental and climate change (4).

In view of the complexity of the processes involved among global environmental and climate changes and their effects on health at different spatial scales, it is essential to bring together and analyze data in such a way as to provide society with actionable information. To achieve this, a set of data on climate,

[1] Instituto de Comunicação e Informação Científica e Tecnológica em Saúde, Fundação Oswaldo Cruz (ICICT/Fiocruz), Rio de Janeiro, Brazil. Send correspondence to Christovam Barcellos, email: xris@fiocruz.br

[2] Unité Mixte de Recherche Espace pour le développement, Institut de Recherche pour le Développement, Montpellier, Languedoc-Roussillon, France.

[3] International Research Institute for Climate and Society, Columbia University, New York, United States of America.

[4] Institut national de santé publique du Québec, Health and Environmental Group, Québec, Canada.

[5] Instituto Nacional de Pesquisas Espaciais, São José dos Campos, São Paulo, Brazil.

environment, population, and health is required. According to Vera and colleagues (5), the main challenges related to disseminating climate data are as follows: construction of partnerships between administrators, users, and civil society, and climate data producers; translation of long-term data into information at the regional and local scales, in accordance with decisionmaking levels; maintenance of a global climate observation system; and procedures for integration, quality assessment, processing, and analysis of databases relevant to climate forecasting. *Observatories* may be a response to the need for opportune, integrated, and quality-controlled data and indicators.

Despite its generalized use, the term "observatory" has a precise meaning that is limited to a building or institution constructed to observe certain phenomena by employing specific tools. According to Gattini (6), a *health* observatory is a virtual platform, a nationwide center that conducts comprehensive observation and produces systematic reports on aspects of population health and health systems to support health policies and plans.

It was in this context that the Brazil's Climate and Health Observatory (C&HO) was developed. Its purpose was to integrate databases and bring together information obtained from agencies and research institutions, with the intention of fostering academic studies and developing technological innovations within the fields of climate and health. What follows is a description of the process of constructing the C&HO, from the perspective of building predictive models and disseminating sentinel sites for monitoring climate and health trends on the regional and local scales. This report also critically examines other existing information systems related to environmental health in other countries. Hence, this work may contribute to other initiatives striving to develop and improve the availability of health and environment indicators.

THE BRAZILIAN CLIMATE AND HEALTH OBSERVATORY

The process for constructing the C&HO began with a selected list of the existing information dissemination systems in Brazil. Each system was analyzed, after a search for environmental health and climate change data sites. The purpose, potential audience, and technological platform of each site were critically examined.

C&HO platform

A prototype version of the Brazilian C&HO platform was developed and deployed (www.climasaude.icict.fiocruz.br) in 2011. As part of the C&HO site, introductory texts were added making it possible to understand the Observatory's aims (presentation, methodology, technology tabs, and a user manual). The "Participation" tab explains the process by which citizens should enter data. Another tab provides access to published studies on the relationships between climate and health in Brazil.

Data can be accessed through a map interface, or by clicking on the "Indicators" tab, which lists available health indicators. In the "Sentinel Sites" tab, three sites that are initially being monitored by the project are listed. Complex queries can be made by users and can be executed over multiple sites, geographically distributed, with all technical details hidden from the end user. At this stage of the prototype, alongside the queries, semi-qualitative graphs and maps can be produced. The platform supports research and development on climate and environmental changes and health effects by providing access to the data. It also promotes active participation by civil society and citizens in the debate on climate and environmental changes and the effects on health and health systems.

Technological approach

An adapted methodology derived from information systems analysis was applied in the C&HO design, involving a requirement analysis and negotiation stage, and a prototyping stage. From a technological point of view, this means that the computational infrastructure was built, tested, and then reworked as necessary until an acceptable *prototype* was finally achieved from which the complete platform could then evolve. From an Information Technology (IT) viewpoint, the methods used were based on open-source software and open Internet protocols and formats, using Open Geospatial Consortium Services Architecture (www.opengeospatial.org). From the *data* point of view, the observatory favors an open data policy. Both are necessary in order to guarantee a low-cost and a truly open knowledge platform that can improve access to health-related climate and environmental data and models.

Conceptual model

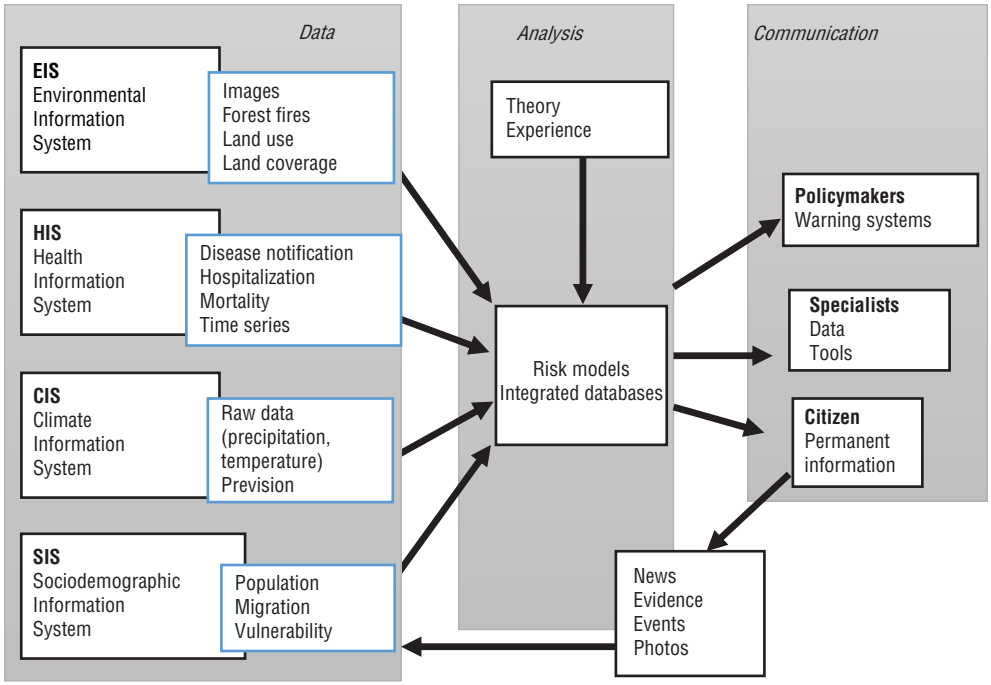
A general framework for the Brazilian C&HO can be seen in Figure 1. It shows the different phases needed for the consolidation of the Observatory. In the first phase, data on climate, environment, population, and health had to be gathered and assembled. The second phase consisted of data analysis and was the meeting point between existing experiences and theories, backed by access to data. The third phase, aimed at communication, was targeted to the possible users: public health professionals and managers, specialists, and citizens. It soon became apparent that simply making the data available would not allow full achievement of one of the Observatory's goals: promoting user awareness of the importance of debating health-related issues regarding climate change trends and extreme events. It was necessary to encourage involvement with shared data and knowledge production geared toward the C&HO-focused thematic.

Data, databases, and indicators

Given the diversity of sources on climate, environment, population, and health information of Brazil, it was necessary to select a minimum dataset that would make it possible to follow up medium- and long-term trends. In the specific framework of the C&HO, this selection task was developed through an organized multi-institutional thematic.

The stage of evaluating the data available and establishing targets and interinstitutional protocols was accomplished at the first workshop for data users and producers, held in May 2009. The available climate and health data sources were presented and evaluated according to the following criteria: (i) how (in what form) and at what frequency the data was available; (ii) what time-period was covered by the data; (iii) the quality of the data; (iv) the spatial extension coverage for the data; (v) the levels of disaggregation and spatial resolution of the data; and (vi) what institutional policies applied to the data.

FIGURE 1. General framework for the Brazilian Climate and Health Observatory (C&HO) including the different phases needed for its consolidation, Brazil, 2010



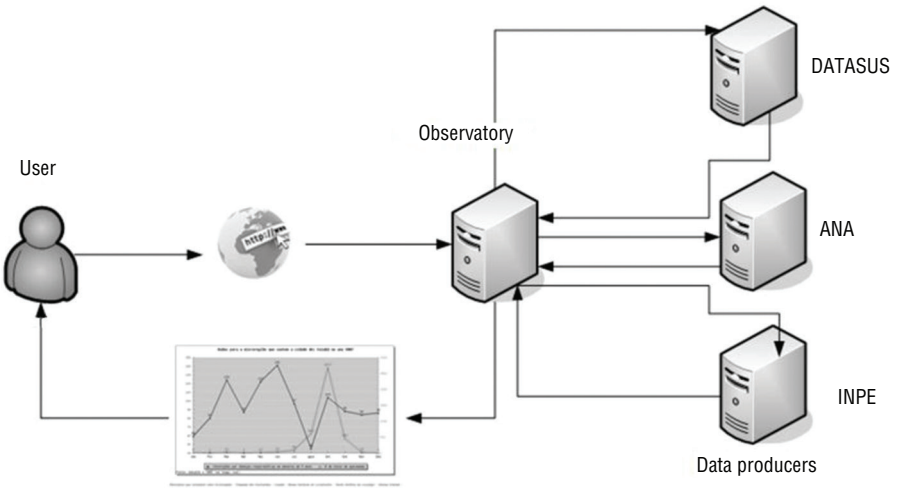
At subsequent workshops, a refined list of indicators and data sources were developed to address health problems that might emerge or be exacerbated by environmental and climatic changes. In July 2010, in Manaus, the second workshop with local specialists and stakeholders was held to define climate and health indicators that could be used to monitor the possible effects of climate change on the hydrological regime of the Amazon River. The Observatory's third workshop took place in Porto Velho in October 2010. It focused on the Amazon area. Its aim was to discuss the situation regarding respiratory conditions derived from forest fires and to select indicators to evaluate and monitor the health effects of exposure to atmospheric pollutants driven by the region's climatic variability. The fourth workshop was held in Rio de Janeiro in November 2010. Its aim was to identify changes in the dynamics of vector-borne diseases, especially dengue, malaria, leishmaniosis, Chagas' disease, and yellow fever, mediated by environmental changes and climate seasonal variability. In December 2011, the Observatory's fifth thematic workshop was held to identify the main health hazards related to extreme meteorological events and their potential for disasters.

Multi-scale approach based on sentinel sites

The C&HO works at the national scale; however, in climate and environment health-related data, often more detailed spatial and temporal information is needed. To address this requirement, the C&HO established a sentinel sites strategy (7). Sentinel sites are charged with acting as warning posts for changes in health conditions related to climate and local environmental changes. The sites were selected according to the quality of available data and the willingness of the local stakeholders to participate—in general, local health authorities, research institutions, and organizations within civil society (8). The following sites should be highlighted: (i) Rondonia, for studies on the effects of forest fires; (ii) Manaus, for studies on water-borne diseases; (iii) Rio de Janeiro, for studies on dengue and climate; (iv) the northeast region, for studies on the impact of drought; and (v) the southern region, for the effects of extreme meteorological events. More recently, a sentinel site was established at the French Guiana/Brazilian border in order to monitor vector-borne diseases, and the possible influence of human mobility and climate on transmission dynamics (9). The results of these local studies make it possible to validate and establish parameters for modelling the underlying mechanisms associated with these diseases at the regional level.

For the city of Manaus (Amazonas state, Brazil), water-borne diseases and the water level in the Negro River were prioritized as indicators of climate change by the second workshop participants. The diagram in Figure 2 shows the structure of the system. A data request can be sent to the Tabnet system (a system for data tabulation at www.datasus.gov.br) and the water resources information system of the *Agência Nacional de Águas* (National Water Agency of Brazil; ANA). The resulting graph (Figure 3) demonstrates the dynamics of the variables over a span of time. Typically, in May – July of each year, the Negro River reaches its annual maximum level, followed by an increase in the number leptospirosis cases. The city experienced extreme floods in recent years, with a historic record in 2012 that compromised water supply and sewage systems. These variables, together with precipitation, are shown in an interactive dashboard that can explored by the end user.

FIGURE 2. Data flow of distributed data sources—Health Informatics Department (DATASUS), National Water Agency (ANA), and National Institute of Space Research (INPE)—and indicator acquisition for the sentinel site of Manaus, Brazil, 2016

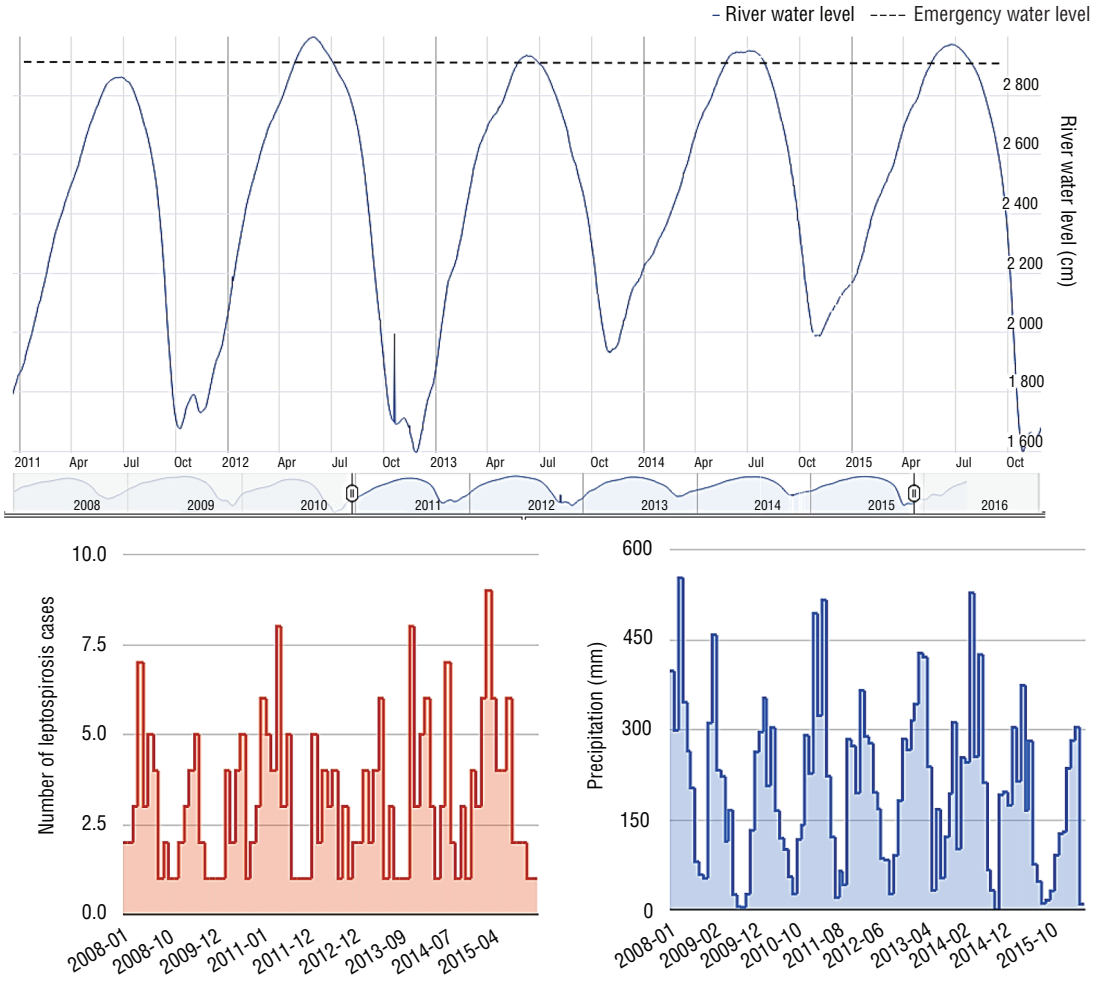


Source: Prepared by the authors with assistance from DATASUS, ANA, and INPE.

Original data management and access

The C&HO operates differently from other solutions for access to the types of data that are currently available. It does not store local copies of the data consulted; instead, C&HO remotely consults the original data where it resides in the institution that created and maintains it. C&HO makes use of the Web Feature Service and Web Map Service among other open standards for exchanging geographical data. Other data servers can be incorporated once these communication protocols are adopted. Thus, the C&HO can be characterized as an open and scalable project and has the ability to manipulate an increasing amount of data.

FIGURE 3. Screenshot of one output from the Climate and Health Observatory: graph of timeline and river level data, precipitation, and leptospirosis incidence in Manaus, Brazil, 2008 – 2015



Source: Prepared by the authors with data from the Health Informatics Department (DATASUS) and the National Water Agency (ANA) of Brazil.

OTHER RELATED INITIATIVES OR OBSERVATORIES

Several initiatives and experiences that can be considered "observatories" have been implemented in the health and environmental sectors. They have a wide range of objectives, methodologies, and technological bases, but share the goal of providing basic data and indicators in different dimensions: epidemiological, demographic, and environmental, allowing an overview of health risks. These are:

- Environment and Health Atlas for England and Wales, produced by the Small Area Health Statistics Unit (www.envhealthatlas.co.uk), provides maps of epidemiological and environmental indicators to monitor environmental health conditions;
- Health Observatory of Colombia (www.ins.gov.co/lineas-de-accion/ons) organizes and analyzes epidemiological indicators to address the social determinants of health;
- Climate and Health Observatory of Spain (www.oscc.gob.es), organized by the Ministry of Health of Spain, aims to disseminate technical information on climate change and health impacts;
- Several public health observatories in France (e.g., *Observatoire Régional de la Santé Provence-Alpes-Côte d'Azur*, www.orspaca.org) that provide indicators on health service provision, environmental issues, and population health conditions, as well as technical reports on urgent themes;
- Malaria Atlas Project (www.map.ox.ac.uk), founded in 2005, offers spatial data for the malaria control in Africa;
- International Research Institute for Climate and Society (IRI) provides access to a wide variety of climatic and environmental data that can be used to study the relationships between climate and malaria (iridl.ldeo.columbia.edu/maproom/Health/regional/Africa/Malaria) and modelling malaria to offer early warnings (10);
- The SUPREME system, developed the *Institut National de Santé Publique du Québec* (INSPQ) in Canada, allows the surveillance and prevention of the impacts of extreme weather events, combining real-time data on weather conditions with population health indicators (11);
- The National Environmental Public Health Tracking Network (http://ephtracking.cdc.gov/), produced by the United States Centers for Disease Control and Prevention, which offers a system of health, exposure, and hazard indicators.
- The World Health Organization (WHO) provides a couple of portals that include other diseases and injuries: Global Health Atlas (http://apps.who.int/globalatlas); and the Centralized Information System for Infectious Diseases (http://data.euro.who.int/CISID).

These web portals differ greatly in their purposes, potential audiences, and technological platforms; however, they all use the Internet to provide data, information, and/or knowledge on epidemiological conditions and environmental/climatic determinants by considering the main factors that affect the health status of large population groups. The complexity of the information varies widely, from raw data to indicators, and from technical texts to media messages, according to each observatory's objective and target audience.

Currently in many countries, government agencies produce and disseminate data on several platforms using different formats for specific subjects, such as meteorological, environmental, demographic, socioeconomic, and epidemiological data. If the objective is to join and analyze the associations among these elements, users often need to access several separate websites and integrate the data into worksheets in order to establish relationships. Users must utilize their own database management tools, along with statistical analysis and geoprocessing software, to do this. This process is time consuming and may require a large investment in staff training. On the other hand, the named observatories offer useful alternatives for collecting and analyzing timely, high-quality data on a single website.

RECOMMENDATIONS

Traits of a successful observatory

A precise definition of "observatory" is hard to come by since they are not defined by a single clear concept, but rather by their functions, objectives, end users, themes, processes, and data of interest (12). Therefore, observatories should bridge the gaps in data acquisition, data services, integration of data into practice, and integration of data and results into policies (13). As identified in the literature, health observatories can play several important roles, and although this is not an exhaustive list, the following five are of overarching importance. Observatories can:

1. Guide policies and practices by developing a body of knowledge on health and its determinants, promoting better cooperation between academia/researchers and policymakers/ practitioners (14, 15).
2. Play a role in monitoring the health status of a population following the temporal evolution of indicators.
3. Facilitate knowledge transfer among organizations, policymakers, and the general population.
4. Serve as centers for integrating trusted data from different sources by collecting data dispersed among numerous organizations and making it available for analysis and interpretation.
5. Offer expertise in the field of measurement and evaluation, most notably by developing indicators and measurements of climatic impacts, disease transmission dynamics, risks, and social inequalities in health.

Collaboration and networking

The C&HO has provided a means of assembling researchers interested in the debate on the effects of climate change on health. The workshops held within the project have made it possible to identify and mobilize researchers who can contribute to a greater understanding of the relationships between climate and health. Recent extreme events, such as torrential rainfall on the coastal mountain range in Rio de Janeiro and fluctuations in river levels, have raised awareness among researchers and citizens regarding the need for preventive action to reduce the impact that climate-related disasters have on health and health systems.

User-driven service

More than anything, an observatory is a service provided by researchers for a broader audience, including decisionmakers and the general public. The construction of observatories is consequentially dialogical. It assumes that health professionals and

managers are aware of the potential use of climate information, and at the same time, that climate service providers understand the epidemiological and operational context of health problems (16). This agreement is built on a base of meaningful and synthetic common indicators established by both data producers and data users, starting from a list of climate-sensitive diseases to their social, environmental, and climatic determinants. Although observatories provide a wide variety of indicators and tools, the final product must be easily understood and intuitive. If the objective of an observatory is the "collection, analysis, and dissemination of information that revolves around observing time trends, statistical patterns, and geographic contrasts between and among regions, countries, and social groups," (17) data visualization tools may facilitate their appropriation by the lay public.

Therefore, observatories are never passive. They involve complex procedures to gather and estimate indicators that, in some cases, modify the scope of the original data. Even for a simple variable, such as temperature, some work should be done to prepare data to be disseminated and well understood. Reanalysis of raw data is often necessary to perform a global assessment of temperature trends, considering seasonal, interannual, and zonal variability. The choice of each indicator and its calculation procedure are important steps in building an observatory.

Restrictions and disclaimers

It is the task of observatories to acquire and transform data from numerous institutions and sources into information and knowledge for the different final users. Therefore, disclaimers are necessary to explain the origin and restrictions of data and methods to ensure that information can be correctly interpreted. The nature, quality, covered period, producer, etc., of metadata should also be clearly provided as stated by the team of the Environment and Health Atlas for England and Wales (www.envhealthatlas.co.uk), the "simple comparison of mapped environmental agents and health conditions cannot be used to indicate causal associations" (18). In some cases, the observatory should indicate methodological alternatives for data analysis (19), and even forbid some types of analyses with the data it provides.

Other data sources

In addition to official data, any information indirectly related to climate change and health could be considered, as in the case of syndromic warning systems (20). Other information, qualitative and informal, can also be of great interest for the monitoring of sociodemographic changes and characterization of disease dynamics, such as mass migration, droughts, or outbreaks, all of which are commonly reported by local newspapers and posted on social media platforms.

Guidelines and policy

Last, but not least, although the C&HO experience has demonstrated the technical and technological viability of a low-cost and open-based solution for gathering and disseminating data, other issues may impede on building an observatory. The accession of each institution to the C&HO depends not only on the adoption of common protocols for data exchange, but also on adaptation to a multi-institutional and multi-disciplinary project. In addition, some national data policy guidelines are imperative for effective advances in the operational constitution of observatories focused on the new challenges imposed by the climate and environmental changes agenda.

Conclusions

In the framework of environmental health, gathering and analyzing data on environment, weather, climate, population, and health is essential for planning actions to adapt to and mitigate climate change. Information needs to be brought together so that the planning actions to increase socioenvironmental resilience can become more effective. This planning needs to be a democratic process that allows participation by different sectors of civil society, administrators, and researchers, with guidance towards motivating present day changes with short-, medium-, and long-term repercussions. Also, when seeking interaction among managers, researchers, citizens, and public health professionals and managers, their different academic backgrounds, languages, and interests should be taken into consideration.

Acknowledgements The authors are grateful for support from Secretaria de Vigilância em Saúde/Ministério da Saúde (Fiotec-VPAAPS-006-LIV-10-2, Rio de Janeiro, Brazil), the Rede Clima, and the Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq processes 552746/2011-8, 404160/2013-1; Brasília, Brazil).

Conflict of interests: None declared.

Disclaimer. Authors hold sole responsibility for the views expressed in the manuscript, which may not necessarily reflect the opinion or policy of the *RPSP/PAJPH* and/or PAHO.

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Manuscript received on 1 February 2016. Accepted for publication on 31 May 2016

Un observatorio para recopilar y difundir información sobre los efectos del cambio ambiental y climático relacionados con la salud

RESUMEN

Este informe tiene el propósito de examinar críticamente las propuestas, las posibilidades y los retos de los observatorios de salud ambiental con especial interés en los procesos del cambio climático. Se realizó un examen crítico de los observatorios de salud ambiental existentes, para lo cual se evaluó su finalidad, los posibles destinatarios y las plataformas tecnológicas. En este informe se describe la ejecución del Observatorio Nacional de Clima y Salud del Brasil dividida en dos fases: 1) la fase de análisis y negociación de los requisitos, cuyo fin fue definir las instituciones nacionales y regionales que tendrían a su cargo la producción y el aprovechamiento de los datos; y 2) los talleres celebrados sobre temas de salud acerca de las enfermedades relacionadas con el agua, las enfermedades transmitidas por vectores, los acontecimientos climáticos extremos y los problemas de salud derivados de los incendios forestales. El Observatorio es un ejemplo de plataforma de internet que ofrece información y datos sobre el clima y la salud provenientes de diferentes fuentes. Los usuarios pueden plantear consultas complejas en varios sitios, localizados en distintas zonas geográficas y todos los detalles técnicos se mantienen ocultos para el usuario. En esta fase de prototipo del Observatorio es posible generar gráficos y mapas semicualitativos junto a las consultas. Además, la plataforma permitió generar una estrategia de varias escalas a través del establecimiento de centros centinela. La creación de un observatorio eficaz es un proceso participativo que comprende la elección de los indicadores, las fuentes de los datos, la tecnología de la información y los idiomas que serán empleados con el propósito de llegar a diferentes públicos, como investigadores, ciudadanos, profesionales de la salud pública y encargados de adoptar las decisiones.

Palabras clave Cambio climático; servicios de información; medio ambiente y salud pública; vigilancia sanitaria; Brasil.