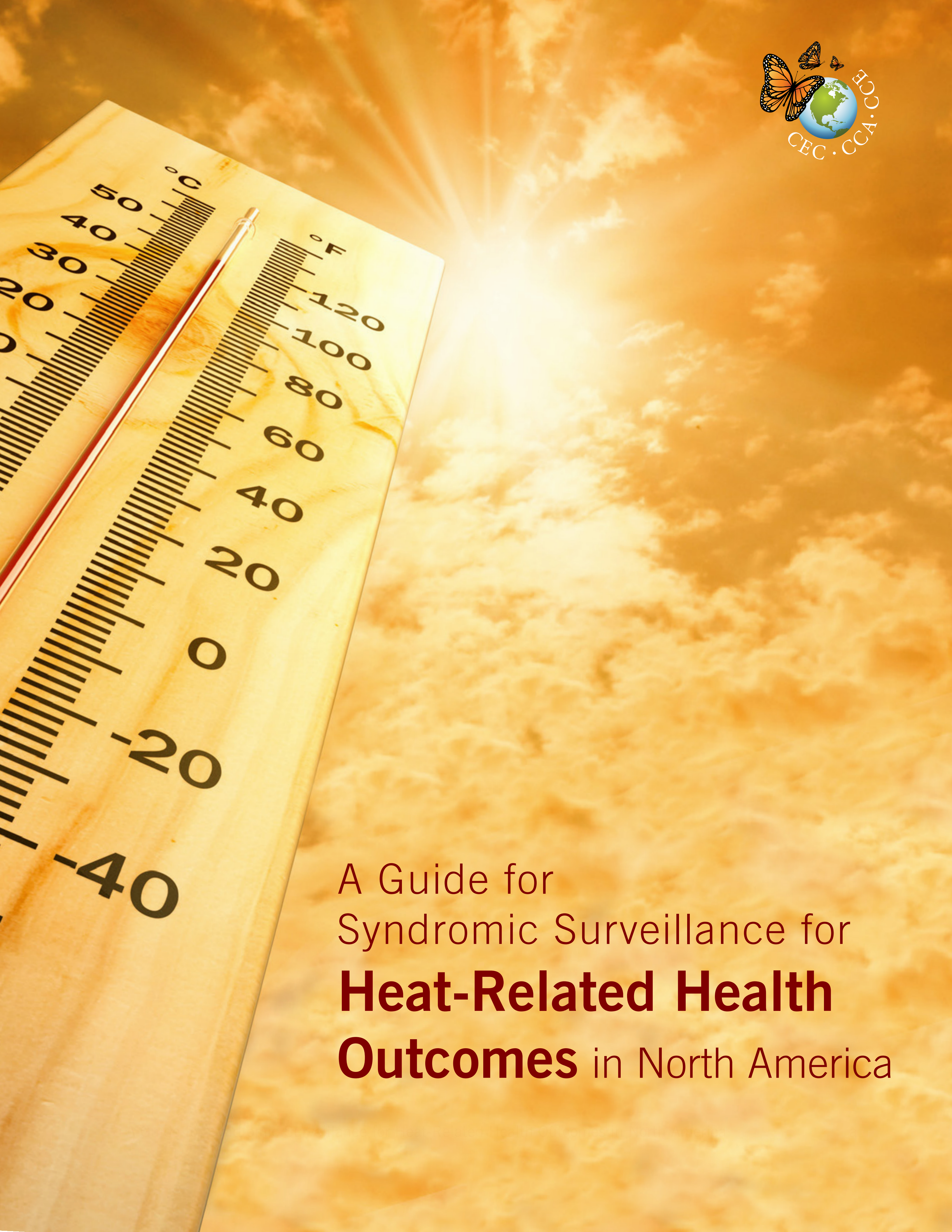

A Guide for Syndromic Surveillance for **Heat-Related Health Outcomes** in North America

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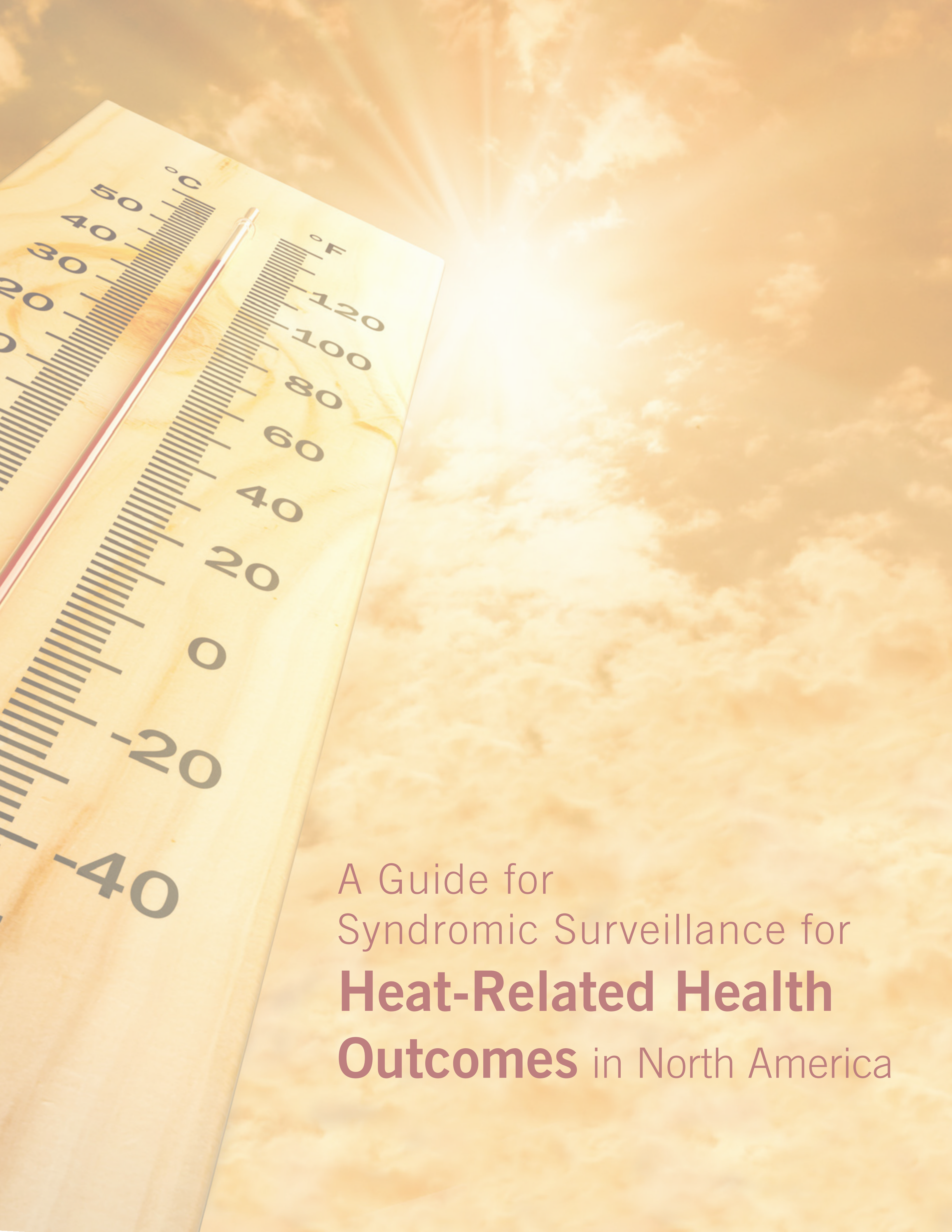
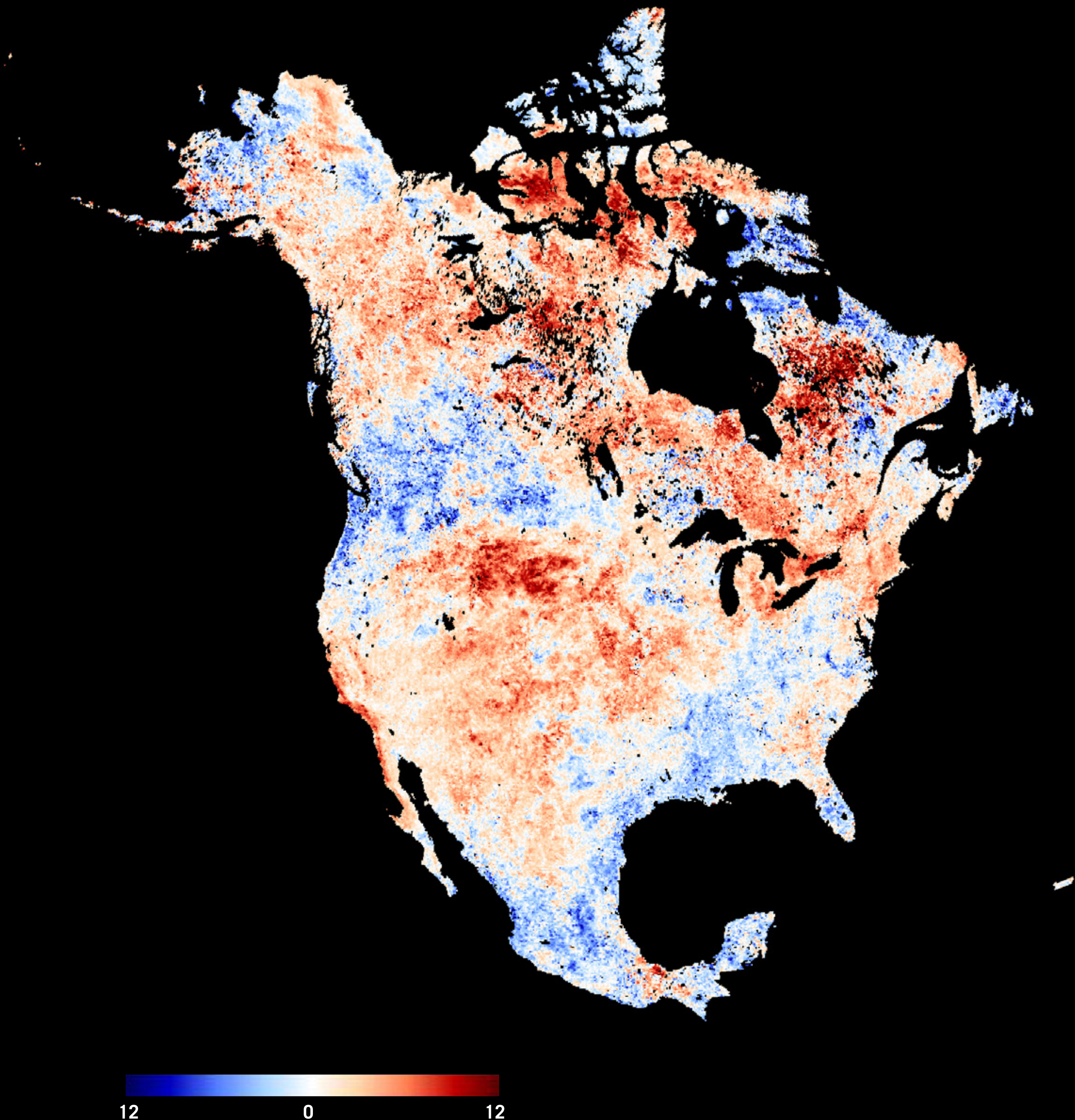


A Guide for Syndromic Surveillance for **Heat-Related Health Outcomes** in North America



Land Surface Temperature Anomaly Map for June 17–24, 2016. Areas in red were warmer than the 2001–2010 average temperature, whereas areas in blue were cooler. (Source: NASA Earth Observations, 2016)

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List of Abbreviations and Acronyms

ACES	Acute Care Enhanced Surveillance
CDC	Centers for Disease Control and Prevention
CHSSW	Climate and Health Syndromic Surveillance Workgroup
CEC	Commission for Environmental Cooperation
Coesprisson	*Comisión Estatal de Protección contra Riesgos Sanitarios del Estado de Sonora* (State Commission for the Protection Against Sanitary Risks of the State of Sonora)
Cofepris	*Comisión Federal para Protección contra Riesgos Sanitarios* (Federal Commission for the Protection Against Sanitary Risks)
CSTE	Council of State and Territorial Epidemiologists
CuSum	Cumulative Sum
EARS	Early Aberration Reporting System
ECCC	Environment and Climate Change Canada
ESSENCE	Electronic Surveillance System for the Early Notification of Community-based Epidemic
GIS	geographic information system
HL7	Health Level 7
HRI	heat-related illness
ISDS	International Society for Disease Surveillance
MDHHS	Michigan Department of Health and Human Services
MSSS	Michigan Syndromic Surveillance System
NLP	natural language processing
NDVI	Normalized Difference Vegetation Index
RODS	Real-time Outbreak and Disease Surveillance
OPH	Ottawa Public Health
OSSEH	Ottawa Syndromic Surveillance for Extreme Heat
SMN	*Servicio Meteorológico Nacional* (National Meteorological Service)
SUPREME	Surveillance and Prevention of the impacts of Extreme Meteorological Events
SurSaUD	French Syndromic Surveillance System
SyS	syndromic surveillance

Abstract

As part of a project of the Commission for Environmental Cooperation, this Guide outlines the steps required to create or enhance a syndromic surveillance system to monitor extreme heat events, and highlights the experiences of three participating pilot communities from Canada, Mexico and United States. A successful syndromic surveillance system uses pre-diagnostic data sources to monitor for early signs of health effects in order to enable early public health response. The five key steps to create (or enhance) a syndromic surveillance system to monitor extreme heat events are: (1) data source identification (including assessment of data suitability, availability, timeliness, and quality); (2) design of system architecture; (3) defining a syndrome to capture heat-related illnesses; (4) defining alerting rules for the system; and (5) integrating health outcomes with weather information (e.g., temperature). The city of Hermosillo, Mexico, built a syndromic surveillance system from the ground up to enable the city's public health surveillance to include heat-related illnesses; the state of Michigan, United States, improved its existing heat syndrome with additional keywords and improved statistical methods for determining alerting protocols; the city of Ottawa, Canada, improved its current syndromic surveillance for heat-related illnesses by adding near–real-time data from a nurse advice telephone service and displaying health outcomes with meteorological data on a map-based dashboard. The experiences of the pilot communities represent numerous lessons to be learned by communities with varied resources and climates as they develop their syndromic surveillance capacity.

Executive Summary

The Commission for Environmental Cooperation engaged three communities in North America, one from each of Canada, Mexico and United States, to participate as pilot communities in the project, *Helping North American Communities Adapt to Climate Change: A Pilot Syndromic Surveillance System for Extreme Heat Events*. The main goal of this project is to develop an operational, real-time syndromic surveillance system for extreme heat events in each of the pilot communities. This guide serves to outline the experiences of the pilot communities by highlighting their lessons learned, and also to identify five key steps to developing a syndromic surveillance system to monitor extreme heat that are relevant to any North American community considering a similar undertaking.

Current climate models predict more severe extreme heat events that can pose risks to human health and thus methods to improve our understanding of the health effects of heat are needed to enable necessary heat adaptations through public health preventative and protective policy and response. Syndromic surveillance augments traditional public health surveillance by using earlier, pre-diagnostic data to monitor health effects. For example, many North American public health authorities monitor seasonal influenza using syndromic surveillance systems based on such data sources as acute care triage data, over-the-counter pharmaceutical sales, or school absenteeism records.

This guide provides a historical overview of syndromic surveillance, and outlines five key steps needed to create (or enhance) a system for monitoring extreme heat events. The experiences and lessons learned by three pilot communities are included within a relevant key step to further demonstrate methods and challenges. One pilot community was selected from each of Canada, Mexico and United States; the communities are the city of Ottawa, the city of Hermosillo, and the state of Michigan, respectively.

The five key steps are as follows, and are discussed in turn:

1. identifying data sources,
2. determining the syndromic surveillance system architecture,
3. defining a heat syndrome,
4. defining outbreak detection alerts, and
5. integrating health outcomes and weather information into a syndromic surveillance system.

The effectiveness of surveillance depends on the characteristics of the data used. The first step to create (or enhance) a syndromic surveillance system is to identify appropriate data sources. Inherent in this step is an assessment of the data source. First and foremost, the suitability of a data source needs to be assessed: do the data provide quantitative measures of heat-related illnesses? Health outcomes related to heat range from mild discomfort to death, and some symptoms may not be identified by healthcare professionals as related to extreme heat (e.g., dehydration is included in the etiology of many diseases). Next the availability of the data is considered, including issues of ownership and privacy. For syndromic surveillance, timeliness of data transfer is paramount. For example, the data need to be available as soon as they are generated, or soon afterwards, in order to monitor health outcomes in near-real or real time. Finally, data quality needs to be considered, including the completeness, accuracy, and representativeness.

The second step is to design system architecture capable of meeting the objectives for the syndromic surveillance system. Architecture is the technical framework of electronic components, including all necessary hardware, software and networks. The city of Hermosillo built a database to collect heat-related illnesses at two medical facilities that made possible effective security and privacy measures as the data collected were collated for analysis and assessment by epidemiological and public health staff. The data collected by this system have improved Hermosillo's understanding of the local health effects of extreme heat, and are being used to augment existing epidemiological reports for infectious and other reportable diseases. The project team hopes to expand the current new database to other medical facilities to further improve situational awareness of heat-related illness in Hermosillo, as well as to inform public health preventative and protective policies.

The third step involves the definition of a heat syndrome. For most syndromic surveillance systems, statistical algorithms are used to classify cases collected by data sources into groupings of medically relevant symptoms, or syndromes. For extreme heat, the syndrome is defined by those cases with symptoms indicating heat-related illness. Depending on the capacity of the system that is created (or enhanced), this may mean defining algorithms to classify cases into a heat-specific syndrome for heat-related illness, or creating ad hoc keyword searches of the data. The Michigan Syndromic Surveillance System participated in this project by improving their syndrome for heat-related illnesses; the project team augmented the list of keywords used to classify cases from triage chief complaints with additional heat-related terms. They also created new statistical methods to allow greater accuracy in identifying aberrations from expected case counts. The lessons learned by the Michigan pilot community are particularly relevant to communities that use syndromic surveillance systems with pre-defined and established syndrome definitions.

The fourth step in creating a syndromic surveillance system to monitor extreme heat events is the creation or definition of alerting rules to identify case counts that are aberrant, or greater than is expected, and therefore deserving of public health response. Several methods for determining aberrant counts are described, included the simple "eyeball" method that experienced analysts can employ, and statistical methods based on preceding or historical baselines. For example, Cumulative Sums is a common alerting method that is based on baselines calculated from the data counts of preceding days (varying according to the sensitivity of the desired detection), and thresholds that can also be varied for sensitivity. Alerting rules need to be defined within alert response protocols, which are ideally developed in collaboration with community stakeholders, and define actions and responsibilities when an alert is generated by the data.

The final step, as defined in this guide, is the integration of health outcomes data with weather data. An ideal syndromic surveillance system to monitor extreme heat events will enable map-based and real-time assessment of health outcomes in relation to real-time climate conditions. Such a system can enable public health response in the geographical regions of greatest risk and/or need, and also allow real-time situational awareness of an event. This information is essential for evaluating current practices and policies both during and following an event, and may enable real-time decision making to improve outcomes during an event. A dedicated dashboard integrating health outcomes and weather information was created for the city of Ottawa: the Ottawa Syndromic Surveillance for Extreme Heat system provides public health professionals immediate access to information regarding acute care usage and nurse advice telephone calls with data feeds from meteorological services in hopes of improving response times during extreme heat events.

The strengths and limitations of syndromic surveillance of extreme heat events using data sources for heat-related illnesses are similar to those observed for other syndromic surveillance systems. For example, syndromic surveillance is based on pre-diagnostic data and should be retrospectively validated against diagnostic data to ensure the effectiveness of the system. The lessons learned by the pilot communities for this project are particularly relevant as the communities represent varied stages of capacity for syndromic surveillance, ranging from a city with no active syndromic surveillance (i.e., Hermosillo) to a city with a well-established and validated system, as well as a dashboard that integrates health outcomes and weather data (i.e., Ottawa). Regardless of the starting point, important improvements were made for the respective syndromic surveillance systems in all pilot communities. For example, it is a common experience for all communities that the identification of data sources and careful collection of the data are integral to creating an effective database for syndromic surveillance. Likewise, data collection by syndromic surveillance is a valuable way of identifying populations and/or geographic regions that are vulnerable to extreme heat. Finally, it is noted that further work is needed to develop combined health and weather indicators to improve heat response plans and emergency protocols.

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Introduction

Climate change presents new challenges to public health and to the health system. Global and regional climate models predict that extreme weather events will increase in frequency, severity and duration over the coming decades; extreme heat events, or heat waves, are expected to be particularly intensified (IPCC 2014). Risks to human health are changing due to increased temperature and weather stress, combined with associated impaired air quality, increased risk for food and water contamination, and changes in transmission patterns of infectious diseases. Rates of morbidity and mortality due to exposure to extreme heat are increasing; for example, the 2003 heat wave in Europe and 2010 heat wave in Russia resulted in 70,000 and 55,000 deaths, respectively (Barriopedro et al. 2011; Robine et al. 2008). Novel methods to enhance traditional public health surveillance to improve emergency response times could improve community resiliency to climate change.

Syndromic surveillance (SyS) allows public health authorities to monitor disease outbreaks using data sources that provide real-time (or near–real-time) access to health information. Efforts to implement or enhance SyS systems for health outcomes related to exposure to extreme heat enable a better understanding of those impacts, and also support emergency and public health responses with evidence-based information and enhanced situational awareness during heat waves. Heat-related illnesses (HRI) include heat rashes, heat exhaustion, heat cramps, and heat (or sun) stroke; exposure to extreme heat can also exacerbate existing chronic illnesses (Hajat, O'Connor, and Kosatsky 2010). Many health authorities across North America already incorporate SyS into their routine public health surveillance practices to detect, for example, the start of the annual influenza season or to monitor local asthma cases. Enhancing existing or building new SyS systems to monitor extreme heat can assist health authorities in their efforts to support population adaptation to climate change.

This guide presents a foundation for the development of SyS systems for monitoring extreme heat events in North America, and lays out the steps needed to build a system where there is no preexisting SyS program, or to enhance a working SyS system for HRI. Case studies from health authorities across North America will be used to highlight lessons learned in these communities as they incorporate SyS for monitoring extreme heat events into their public health surveillance practices. Case studies are selected from communities participating in a project sponsored by the Commission for Environmental Cooperation (CEC) and supported by the federal level health authorities of Canada, Mexico, and the United States. A system for recording HRI is outlined from theoretical conception to implementation in the city of Hermosillo, Sonora, Mexico; the Michigan Syndromic Surveillance System (MSSS) re-defines its heat syn-

drome definition to improve detection specificity for the state of Michigan, United States; and the Acute Care Enhanced Surveillance (ACES) in the city of Ottawa, Ontario, Canada, is improved with additional data sources and simultaneous real-time weather data. This project to support SyS in the pilot communities provided the impetus to create this guide.

The guide begins with a primer on SyS to emphasize its history and applications, followed by a summary of the results from a survey of United States and Canadian SyS systems, including a description of commonly used SyS platforms. Five key steps are identified to support public health authorities develop and implement SyS systems for extreme heat. These include the following:

1. identifying data sources,
2. determining the SyS system architecture,
3. defining a heat syndrome,
4. defining outbreak detection alerts, and
5. integrating health outcomes and weather information into a SyS system.

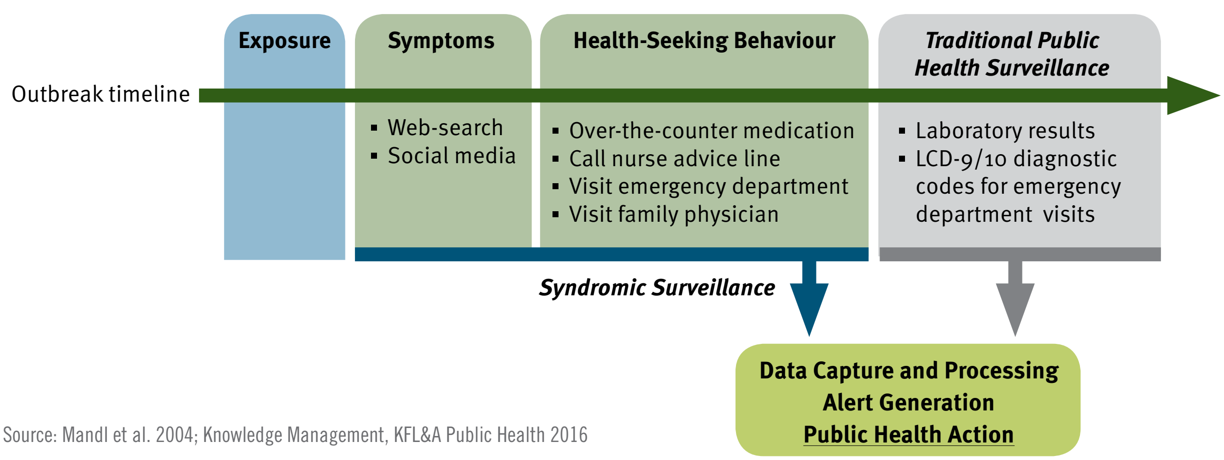
Each step will be discussed with reference to the experiences of the participating communities and health authorities when applicable. A list of resources for more information is provided. This guide is expected to be read with knowledge that a SyS system must be built or enhanced with respect to the characteristics and the level of vulnerability of the local population and available datasets, as heat resiliency and adaptation capacity vary by population. For example, all inhabitants of a community may be vulnerable to heat due to local geography (e.g., high concentration of asphalt with limited shade and vegetation) and socio-economic factors (e.g., low-quality building materials for homes and limited access to air conditioning), but the most vulnerable may be the oldest and the youngest residents who may be at risk due to physiologically limitations. Likewise, regional implications of climate change will vary across North America. A range of climates and populations are presented in this guide to highlight the range of methods that can be used to implement effective SyS.

A Primer on Syndromic Surveillance

Brief Historical Overview

Traditional public health surveillance is the ongoing and systematic collection, analysis and dissemination of health-related data with the goal to reduce morbidity and mortality by informing public health action (German et al. 2001). SyS is public health surveillance that uses real (or near-real) time pre-diagnostic data and statistical tools to detect unusual health patterns or signals with the goal of reducing the time to detect and respond to outbreaks that will be a public health concern (International Society for Disease Surveillance 2007a). A syndrome is a predefined grouping of symptoms (or health indicators) that may indicate a clinical diagnosis or specific health outcome, but do not require laboratory diagnoses for confirmation (e.g., school absenteeism during influenza season). The strength of SyS lies in its timeliness: early public health response can potentially reduce the impact of an outbreak through targeted resource allocation and timely emergency services. Figure 1 shows the potential improvement in the timelines of detection using some typical data sources. The characteristics of traditional public health surveillance and SyS are shown in Table 1. Depending on the timeliness of the data used, the potential for preventative or protective public health action can be significantly enhanced using SyS.

Figure 1. Potential timelines of detection for syndromic surveillance versus traditional public health surveillance



Source: Mandl et al. 2004; Knowledge Management, KFL&A Public Health 2016

Table 1. Features of traditional public health and syndromic surveillance

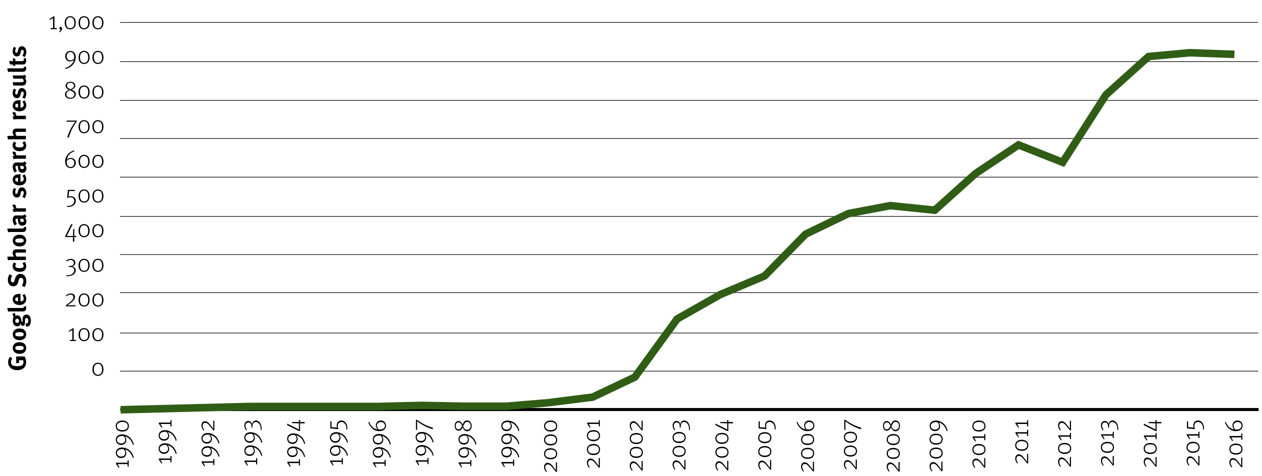
	Traditional Public Health Surveillance	Syndromic Surveillance
Data source	Diagnostic data from case reports from health care providers and laboratory reports	Pre-diagnostic data collected for other purposes (e.g., triage records from acute care facilities, over-the-counter pharmaceutical sales records, school absenteeism records)
Timeliness	Days to weeks	Immediate (real time) to hourly or daily (near-real time)
Goal	To identify and investigate individual cases or clusters of cases, or unexpected activity	To identify excess case counts or unusual case distributions, highlight aberrant activities for further public health investigation
Use	Monitor reportable diseases, routine public health surveillance	Initial focus on detecting bioterrorism; developed into methods to monitor influenza seasons, asthma activity, carbon monoxide poisoning, etc.
Data transfer methods	Telephone/fax transfer of records, paper records	Automated electronic data transfer

Source: International Society for Disease Surveillance 2007a

Public health surveillance does not focus on individual cases, but explores health outcome trends for population health (Thacker 2000). Surveillance approaches resembling SyS first appeared in the 1980s in developing countries where diagnostic tests confirming infectious diseases were not available or were significantly delayed (e.g., Jacob John et al. 1998). Research interest into early warning systems that did not rely on diagnostic data but could accurately predict disease outbreak surged at the onset of the 21st century to monitor for the dual threats of bioterrorism and pandemic, for example, the SARS (severe acute respiratory syndrome) epidemic, or the H1N1 and H5N1 influenza epidemics. The results of a Google Scholar search for the term "syndromic surveillance" in peer-reviewed articles, government or private sector research reports, dissertations, and conference abstracts shows that interest in the topic surges after September 11, 2001, and the SARS epidemic of 2002–2003 (Figure 2).

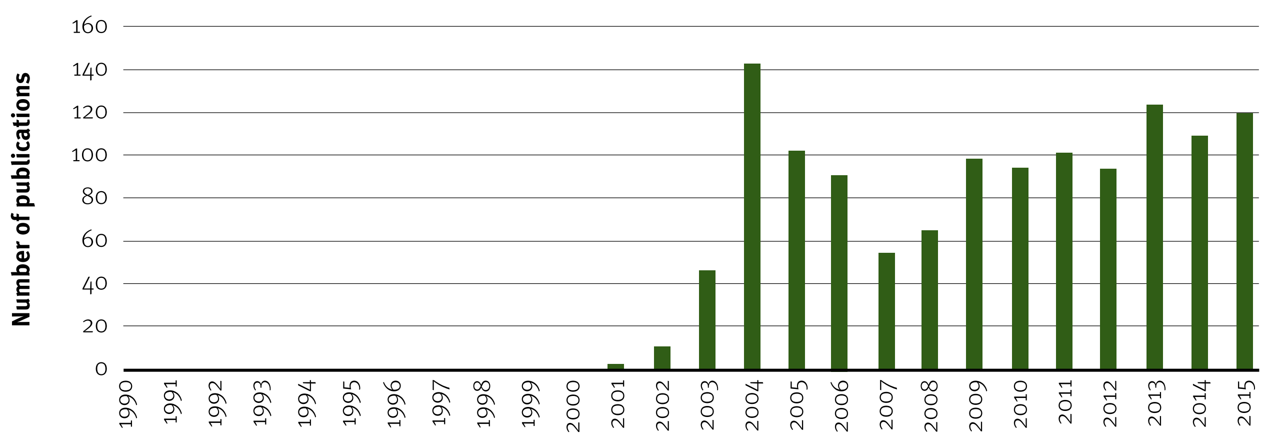
A comprehensive analysis of recent publishing trends was made using the search engines Ovid Embase and Ovid MEDLINE (Figure 3). Embase is a biomedical database and MEDLINE collates both biomedical and life sciences information. The databases were searched

Figure 2. Google Scholar search results for "syndromic surveillance" anywhere in article



Source: Knowledge Management, KFL&A Public Health 2016

Figure 3. The number of publications per year with the search phrase "syndromic surveillance" (in title or abstract) using Ovid Embase and Ovid MEDLINE



Source: Knowledge Management, KFL&A Public Health 2016 for peer-reviewed articles with the keyword phrase "syndromic surveillance" in the title or abstract. Again, surges in research interest correlate with September 11 (2001) and SARS, but a survey of the systems described in the peer-reviewed articles shows the wide breadth of applications (e.g., infectious diseases such as seasonal influenza and dengue or West Nile Virus, asthma, sexually-transmitted infections, spider bites, situational awareness of mass gatherings or public health emergencies such as terrorist attacks or natural disasters, gastrointestinal outbreaks). About 20 percent of articles describe veterinary SyS systems, and nearly half describe studies from Europe, reflecting a relatively mature pan-European SyS system (Triple-S, Syndromic Surveillance Systems; http://www.syndromicsurveillance.eu/).

Applications of Syndromic Surveillance

The development of varied SyS methods and systems reflects its adaptability, from simplistic systems with low technological demands to complex computerized systems. A simple system may rely on the regular transmission of pre-determined reports of symptoms and/or syndromes to a centralized database. A complex computerized system will feature automated data extraction, algorithms to classify individual records into pre-defined syndromes, statistical methods to determine aberrations from expected values, and automated communication processes with stakeholders. Pre-diagnostic data are requisite to ensure the timeliness inherent in SyS as the underlying motivation is to provide treatment or protection strategies as early as possible in a health-related event. An ideal SyS system does not rely on any active or new input and relies on passive surveillance where data are already being collected for other health purposes. Table 2 lists the various data sources that have been used, sorted as non-clinical and clinical sources. It is important to reiterate that these pre-diagnostic data are used to assess population health and are not meant to be used for clinical case identification. The data sources in Table 2 are not listed in order of timeliness, but social media and web searches may be the timeliest data sources. Likewise, the timeliness of the electronic medical records depends on the frequency of data input and transfer. Data sources vary in quality and the breadth of information they can offer: for example, electronic medical records may include age, sex, and other demographic information.

Most commonly, SyS is used to monitor infectious diseases and pathogens. For example, the Electronic Surveillance System for the Early Notification of Community-based Epidemic (ESSENCE, previously referred to as BioSense) platform was developed by Johns Hopkins University, and is used in many jurisdictions throughout the United States. It is a cloud-based system that collects emergency department triage records and sorts each visit into ten standardized syndromes using keywords and phrases found in

Table 2. Non-clinical and clinical data sources for syndromic surveillance

Non-Clinical Data Sources	Clinical Data Sources
Social media postings of symptoms (e.g., Twitter, Facebook)	Nurse advice telephone line
Symptom/health topic-related web searches	School nurse electronic records
Over-the-counter pharmaceutical sales	Poison control telephone calls
Sales of other health-related items (e.g., humidifiers)	Family physician practice/walk-in clinic/urgent care clinic electronic medical records
Work or school absenteeism	Emergency department triage records (chief complaints, nurses' notes)
Ambulance dispatch data	Laboratory test requisitions
Zoonotic disease surveillance data (e.g., rabies from dog bites)	Prescription drug sales
	Outpatient admissions records

Source: International Society for Disease Surveillance 2007a the chief complaint. Those syndromes are: (1) botulism-like, (2) exposure, (3) fever, (4) gastrointestinal, (5) hemorrhagic illness, (6) influenza-like illness, (7) injury, (8) neurological, (9) rash, and (10) other. The syndromes reflect the historical interest in using SyS to monitor potential bioterrorist attacks, as well as its strengths for influenza tracking, monitoring disasters, and identifying foodborne illnesses. ESSENCE also includes other pre-defined queries; for example, a 'heat excessive' query is available that can be locally refined to monitor HRI (Patel and Hoferka 2014; White, Goodin, and Berisha 2015). In addition to traditional infectious disease surveillance, SyS is increasingly being used to monitor chronic diseases or injuries. In a survey of US SyS system users (mostly identifying as ESSENCE users), the top five syndromes reported to be routinely monitored were (1) influenza-like illness, (2) gastrointestinal, (3) respiratory, (4) heat-related illness, and (5) agents of bioterrorism (Roach 2016).

Syndromic Surveillance Systems to Monitor Extreme Heat

In 2015, United States and Canadian SyS users were surveyed by the Climate and Health Syndromic Surveillance Workgroup (CHSSW), supported by the Council of State and Territorial Epidemiologists (CSTE), regarding the use of SyS systems for monitoring heat-related health outcomes as well as all general illnesses/injuries related to extreme weather events and climate change. The CHSSW is a joint initiative of public health agencies in Canada and the United States.

In Canada, in addition to heat-related morbidity and mortality, preventable health impacts from climate change include damage from permafrost melt, expansion of vector habitats (such as that of ticks carrying Lyme disease), health impacts from storms, dangerous driving conditions, changes in drinking water quality and quantity, and food security impacts from changing animal distributions. Canada's federal health authority, Health Canada, advocates the use of a collaborative, capacity-building model to increase community resiliency to climate change health impacts, with evidence-based information to support decision-making. For example, Health Canada supported the development of community-based heat health triggers based on population health outcome data and observed temperatures for each province (Ministry of Health and Long-Term Care 2016). At present, health data related to heat-health outcomes are collected in separated systems and there are neither common data collection standards nor a real-time national system to collect climate-related health outcomes.

The CHSSW survey was distributed to a list of known SyS system administrators and users in Canada and the United States in fall 2015; in Canada, all respondents reported using existing SyS to track health outcomes during extreme heat events. Two respondents report the use of the Surveillance and Prevention of the impacts of Extreme Meteorological Events (SUPREME) system that monitors telehealth calls, acute care visits, and ambulance usage in the province of Quebec. SUPREME allows for the simultaneous monitoring (i.e., in the same dashboard) of both meteorological variables and health outcomes. Three respondents use the Ontario-based Acute Care Enhanced Surveillance system (ACES) that uses emergency department triage data from most provincial hospitals. The administrators of ACES provide a web-based situational awareness tool, the Public Health Information Management System (PHIMS), that brings together data feeds from multiple sources, including meteorological (real time and forecast), transportation, emergency management, population demographics and aggregated health outcomes for specific syndromes derived from ACES. PHIMS provided situational awareness for the 2015 summer Pan Am/Parapan Am Games in Toronto, Ontario; an environmental syndrome, including heat-related illnesses, was developed and piloted for use during the Games to aid in monitoring the effects of exposure to extreme heat.

In the United States, the surveillance of climate and health effects at a national level is overseen by the Centers for Disease Control and Prevention (CDC). Identifying populations vulnerable to health impacts from climate change and providing support to local agencies to prevent and adapt to current anticipated health impacts is a CDC goal. The Building Resilience Against Climate Effects (BRACE) Framework was

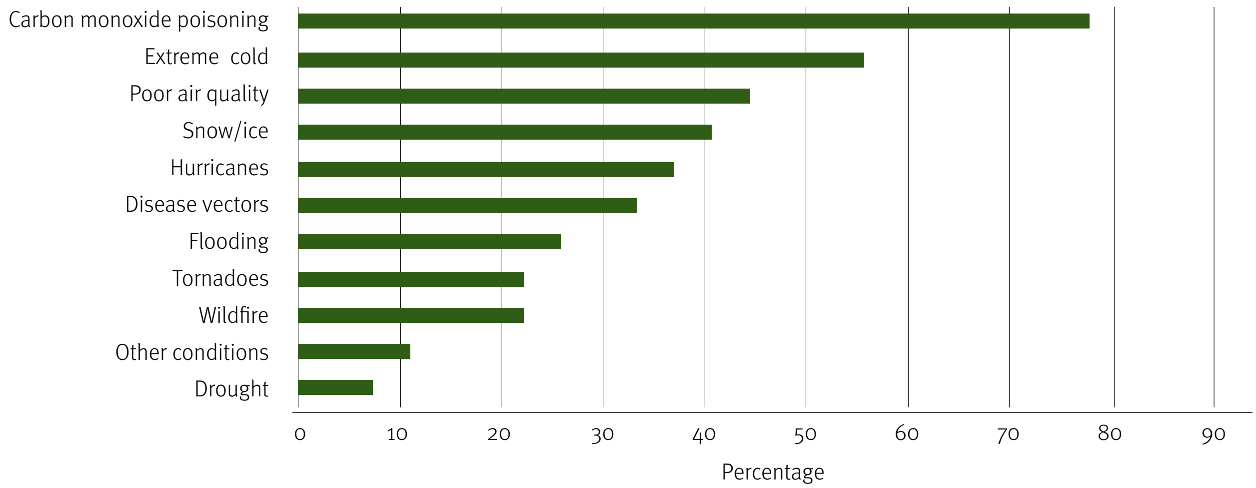
developed to assist this. The framework comprises continuous cycles to: (1) forecast effects and assess vulnerabilities, (2) project disease burden(s), (3) assess public health interventions, (4) develop and implement adaptation plans, and (5) evaluate the impact of programs and improve their quality (Manangan et al. 2015). Any health impacts due to climate change in the United States would be strongly affected by differences in geography and local climate, and can be expected to result in different regional temperature thresholds for health impacts. Understanding these risks is critical to informing public health response.

The National Environmental Public Health Tracking Network is a CDC-sponsored initiative that enables analysis of historical (that is, not real time) health data on extreme heat and vulnerability analytics by geographical region; vulnerable regions can be determined and policies developed to target those populations. Early warning systems, like SyS, can provide cost effective health intervention for heat-health outcomes. These will work particularly well when the system includes weather forecasts that are calibrated for levels of temperature according to health outcomes, with the goal of targeting vulnerable populations, such as outdoor workers and athletes with appropriate messaging. The CDC provides several technical guidance documents regarding heat health, including determining the vulnerable populations and associated disease burdens (e.g., Hess et al. 2016, Manangan et al. 2015).

SyS in the US varies by jurisdiction, with no universal federal system in place; however, the CDC and the International Society for Disease Surveillance (ISDS) support regional and state-wide adoption of the ESSENCE platform as a community-owned model with the capacity to share data for regional and national situational awareness. Jurisdictions wishing to implement ESSENCE can use the American Recovery and Reinvestment Act of 2009, which provides financial support to adopt *meaningful use* of electronic medical records and create better integration between public health and healthcare. Launched in 2003, ESSENCE is available free-of-charge and benefits from easy access to resources to support its adoption and use. ESSENCE is based on emergency department and inpatient admissions records; syndromes are based on pre-defined keyword queries of triage free-text chief complaints, and the system includes built-in analytics and syndrome queries, but is compatible with data processing tools such as SAS. A heat-specific syndrome query is included that can be customized for regional differences, such as Spanish terms.

The CHSSW survey distributed in 2015 to United States SyS users and stakeholders received 40 responses from 36 unique agencies, all representing state or territorial public health agencies. Of these, ESSENCE was the most common platform; other platforms include EpiCenter (a system hosted by Health Monitoring Systems, Inc.) and several regionally unique systems (e.g., the state of New York uses

Figure 4. Of the syndromic surveillance systems that monitor extreme heat, the percentage of syndromic surveillance systems that monitor the health effects of other climate change-related weather events



Source: Matthew Roach 2016

an in-house system based on chief complaints from emergency departments called the Electronic Syndromic Surveillance System). All survey respondents deliver their data electronically and 57 percent of these update data daily. All respondents had the ability to modify syndrome definitions. Approximately 60 percent of respondents reported using SyS to monitor extreme heat; of those, most used SyS to monitor other weather events that are affected by climate change (Figure 4). Carbon monoxide poisoning is included, as exposure rates are generally higher during power outages caused by storm events (or in times of excessive demand on the power grid during heat waves); exposure can occur, for example, with the misuse of gas-powered electrical generators or stoves.

The Health Ministry of Mexico has a National Epidemiology Surveillance System that requires healthcare providers to routinely report pre-defined symptoms for several syndromes and reportable diseases; these surveillance reports are collected and published weekly, and are currently being expanding to monitor health outcomes for extreme heat events. This system, however, does not provide the real- or near–real-time data collection and transfer necessary for a SyS system that could provide early detection of HRI during an extreme heat event nor the situational awareness and timely public health response during an event. The Federal Commission for the Protection Against Sanitary Risks (Cofepris), a federal agency under the Ministry of Health in Mexico, is the regulatory authority for regulation, control and enforcement to protect public health, specifically in mater of harmful environmental factors effects, as environmental health.

A principal goal for Cofepris is to increase heat resiliency in Mexican communities by developing a system for reporting, analysing, and communicating epidemiological and environmental risks in a National Atlas of Sanitary Risks. At present, this system is in place for risks that would affect water quality and plans are pending to expand this to health impacts from climate change. Indeed, increasing morbidity and mortality rates due to extreme heat were observed between 2010 and 2016. Cofepris has identified challenges to these goals as the lack of an integrated reporting system, common data collection standards, methods to differentiate workplace versus residential exposures, and strategies to effectively communicate heat health risks to the public.

Beyond North America, SyS systems have been used in Europe for identifying health impacts during several recent severe heat waves, which have resulted in substantial numbers of excess deaths and high rates of HRI. For example, an extended extreme heat event in the summer of 2003 caused an estimated 70,000 excess deaths in Europe (Pirard et al. 2005; Robine et al. 2008). The French Syndromic Surveillance System (SurSaUD) has been in use since 2004 to detect and monitor unexpected public health events and monitor known events. SurSaUD can trigger alerts to public health authorities for a number of climate-related events using meteorological and biometeorological indicators, such as heat stroke, hyperthermia, dehydration, and hyponatremia. This system is routinely used to assess health impacts during heat waves (Caserio-Schönemann et al. 2015). Similarly, three United Kingdom-based SyS systems, which independently monitor physician consultation records, physician out-of-hours records, and emergency department records, are used collectively to monitor healthcare usage during extreme heat events (Smith, Alex J Elliot, et al. 2016a; Smith, Alex J. Elliot, et al. 2016b).

Using Syndromic Surveillance to Assist Public Health Response

The overarching goal for SyS for HRI is to reduce morbidity and mortality associated with extreme heat events. The governments of Canada, United States, and Mexico have supported the development of policies and action plans to mitigate the health effects of climate change. Various guidance documents are available to support the development of heat warning and response systems; the general steps used to approach the development of these strategies include: (1) assessing the heat-health vulnerability of the local population, (2) developing thresholds and protocol for heat warnings, (3) developing response plans, and (4) improving the system through evaluative cycles (Health Canada 2012). Education and heat-health risk messaging are essential steps to communicating the health risks associated with extreme heat events and encouraging the behavior changes needed to mitigate health effects.

In general, the populations that are at higher risk for heat-related health effects are those that are also considered vulnerable for most social determinants of health. Table 3 lists populations that may be at higher risk for heat-related health outcomes; risk increases for people with multiple risk factors (e.g., an older adult with multiple chronic illnesses living alone in social housing). To assess population heat vulnerability, epidemiological

Table 3. Populations that may be at higher risk for heat-related mortality and morbidity

Heat-Vulnerable Populations
Geographically-isolated (e.g., limited access to immediate health care)
Infants, young children (e.g., reduced physiological protective response)
Newcomers and transients (e.g., immigrants, tourists)
Older adults (e.g. reduced physiological protective response)
Outdoor labourers (e.g., farmers, construction workers)
People accustomed to normally cool climates (e.g., extreme heat events in northern climates can have a greater impact)
People taking medications that interfere with heat regulatory processes
People who are physically active (e.g., athletes)
People with chronic health conditions (e.g., limited mobility due to obesity)
Physically disabled people (e.g., limited mobility)
Socially-disadvantaged people (e.g., homeless people. people living alone, older adults living alone)
Materially-disadvantaged people (e.g., low-income earners, people living in sub-standard housing)
Urban residents (e.g., exposed to higher temperatures due to the urban heat island effect)

Source: Health Canada 2011, 2012; Kenny et al. 2010; Kravchenko et al. 2013; Voogt 2004

Table 4. Ontario Heat Warning Regions and associated conditions and time of duration

Heat Warning Region	Condition			Duration
Extreme Southwestern	maximum daily temperature greater than **31°C** and minimum daily temperature greater than **21°C**	***OR***	humidex greater than **42**	2+ days
Southern	maximum daily temperature greater than **31°C** and minimum daily temperature greater than **20°C**	***OR***	humidex greater than **40**	2+ days
Northern	maximum daily temperature greater than **29°C** and minimum daily temperature greater than **18°C**	***OR***	humidex greater than **36**	2+ days

Source: Ministry of Health and Long-Term Care 2016

methods are used, such as the recommended steps included in the CDC guidance document, *Assessing Health Vulnerability to Climate Change: A Guide for Health Departments* (Manangan et al. 2015):

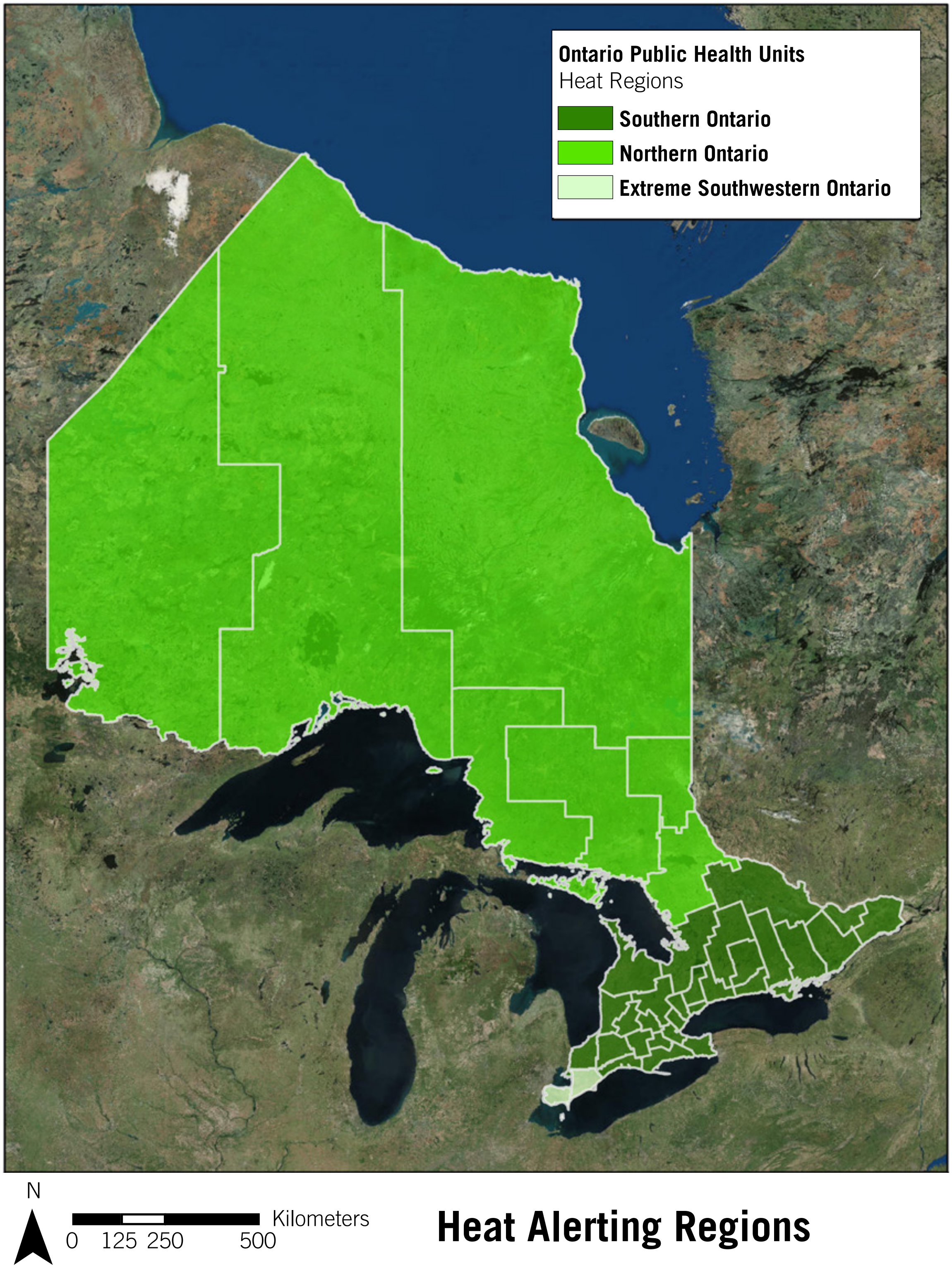
1. define the areas and timelines of interest for the assessment, and gather all relevant data for climate exposure (e.g., daily temperature, humidity and precipitation data) and health outcomes (e.g., rates of HRI, injuries, and/or chronic diseases);
2. for the health outcomes analyzed, identify all known risk factors, such as demographic and environmental factors;
3. collate health outcomes and risk factors at the smallest possible geographical administrative unit available (e.g., zip code);
4. assess the population's adaptive capacity, or the system's ability to cope with and/or reduce the health risk, through financial resources, health infrastructure, adaptive technology and policy (e.g., tree-planting); and,
5. assess the vulnerability using both quantitative methods (e.g., spatial regression analysis) and qualitative methods (e.g., analysis of the quality of resources available).

Using methods based on geographic information systems (GIS) will greatly improve spatial analyses of vulnerability, as layers of information can be directly compared and relationships inferred using spatial techniques. Timing of exposure should also be considered as, for some populations, health impacts may be more severe early in the summer than later (Lee et al. 2014).

With an evidence-based understanding of local heat vulnerability, heat thresholds can be developed. Presently, several jurisdictions in North America have heat warnings that are issued by the respective meteorological and/or health authorities to notify the public when behaviors need to be modified to reduce heat-health risks. Heat warnings are issued by Environment and Climate Change Canada (ECCC) in Canada, the National Oceanic and Atmospheric Administration in the United States, and the National Meteorological Service (*Servicio Meteorológico Nacional* – SMN) in Mexico. Different methods to determine heat thresholds and communicate heat risk are used in each country. However, heat warnings provide the greatest protection for the community when they are based on region-specific observations (Hajat et al. 2010). The federal and provincial health authorities in Canada have produced region-specific heat warning protocols based. The Ontario Ministry of Health and Long-term Care, for example, has defined three region-specific heat warning triggers for the province of Ontario that are based on the region-specific relationship(s) between mortality, air temperature (or humidex), air pollution, and climate and population characteristics. Each local public health agency in Ontario is responsible for administrating heat warning protocol within their boundaries (Ministry of Health and Long-Term Care 2016). Specific heat warnings for each region are shown in Table 4 and the corresponding regions in Figure 5. Heat warnings are issued for two-day events; extended heat warnings are issued for heat events more than two days in length.

Regional heat warning protocols and response plans must be developed in collaboration with community

Figure 5. Map of Ontario heat regions



Source: Ministry of Health and Long-Term Care 2016

Figure 6. Communication protocol for heat warning processes for Environment and Climate Change Canada (ECCC), local public health units (PHU), and community partners

MONITORING	EARLY NOTIFICATION	HEAT WARNING	EXTENDED HEAT WARNING	DE-ESCALATION
• ECCC monitors weather forecast	• ECCC notifies PHUs of forecast meeting warning criteria • ECCC issues warning 12-18 hours in advance	• ECCC advises PHUs that weather criteria met • PHUs advise municipalities and community partners • PHUs notify media	• PHUs notify municipalities and community partners • PHUs act within context of local plans	• ECCC notifies public • PHUs notify municipalities and community partners • PHUs act within context of local plans

Source: Ministry of Health and Long-Term Care 2016

partners and stakeholders, including meteorological services, public health authorities, medical services (acute care facilities and emergency medical services), and other community and emergency management stakeholders. Response protocols are the instructions for action to be taken when heat warning thresholds are predicted or experience, usually consisting of the officials that need to be contacted and the actions that will be taken to initiate a response plan. Response plans take into account the specific needs of the community with specific plans made for different possible scenarios; special attention should be given to the most heat-vulnerable. Protecting a community from heat stress takes a concerted effort; for example, air-conditioned libraries and other municipal buildings can often serve as cooling centres, paramedics may check in on incapacitated clients, and public health nurses can distribute water in vulnerable neighborhoods. A protocol for communicating heat warnings is shown in Figure 6; the communication protocol between ECCC, the public health units (referred to as PHU in the figure), and various community partners should be considered for all stages of the heat warning.

Response plans need to include communication strategies to optimize messaging to the public for maximum uptake. Communication strategies need to be (1) long term, raising heat-health risk awareness and knowledge of protective actions and resources before an extreme heat event, and (2) short-term, addressing immediate dangers when an extreme heat event is occurring. *Communicating the Health Risks of Extreme Heat Events: Toolkit for Public Health and Emergency Management Officials*, provides in-depth discussion of messaging to the public, including steps to evaluate communication campaigns to improve messaging (Health Canada 2011).

SyS can assist these methods in several ways, including the provision of:

- evidence of health impacts during an extreme heat event,
- evidence of health impacts for vulnerable populations during an event,
- data to determine local heat thresholds,
- data to validate local heat thresholds,
- real-time information of health outcomes during an extreme heat event to assist in the allocation of public health resources, and
- real-time information of health outcomes to evaluate communication methods used to issue heat warnings.

Methods for Syndromic Surveillance to Monitor Extreme Heat Events

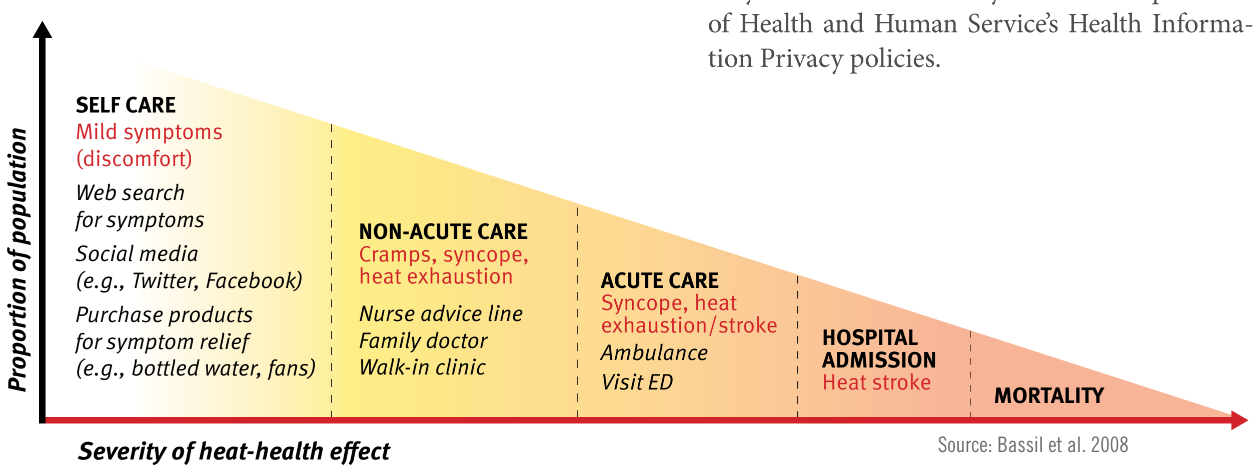
1 Data Source Identification

The effectiveness of a SyS system relies first on the quality and sources of its data; passive data, or pre-existing data, is an alternate option that reduces costs and requires no additional work for health care workers and professionals. The use of multiple data sources can potentially improve SyS through increasing the representativeness of the system for its population and its overall sensitivity. Data sources identified for potential use in a SyS system need to be considered according to (1) suitability, (2) availability, (3) timeliness, and (4) quality. These four requirements are discussed in the context of a SyS for extreme heat events and HRI below:

1. **Suitability** refers to the appropriateness of the data in providing quantitative measures of HRI for a given population. Health outcomes range from mild discomfort to death. The proportion of the population that experience heat-health effects decreases with the severity of the effect (Figure 7). Using measures of behavior occurring closest to the onset of extreme heat exposure will provide the earliest detection, but may not be representative of only HRI. For example, a search of keywords used in Twitter posts may include the words "heat wave"; tweets may indicate early indications of discomfort, but not necessarily. This example illustrates sensitivity versus specificity; the social media search may provide a sensitive indication of people communicating about heat, but it is not a specific measure of HRI. On the other end of the spectrum, deaths from extreme heat provide specificity, but as they are relatively rare, they do not provide a sensitive measure of the health effects of heat. Choosing suitable data sources involves balancing sensitivity and specificity with availability.

2. **Data availability** is dependent on several factors, including accessibility (e.g., data ownership, data collection and storage protocols, data transfer methods), and legalities shaping privacy and sharing agreements. Ideally, SyS is a passive process; therefore, data sharing includes the costs of setting up and operating the data transfer. In some cases, due to privacy concerns, only aggregate data can be shared. The reader is encouraged to consult with local health information policies: in Canada, health information is protected under the authority of the Office of the Privacy Commissioner of Canada, in Mexico patient clinical files are under the protection of the Ministry of Health, and in in the United States, health information privacy is under the authority of the US Department of Health and Human Service's Health Information Privacy policies.

Figure 7. Spectrum of heat-health outcomes



Source: Bassil et al. 2008

3. Early detection requires strict timelines. **Timeliness** can be measured in a number of ways, but is generally anchored from the first exposure in the public to the various time points that can be subsequently measured, such as:

   i. onset of symptoms,
   ii. measurable behaviors (e.g., Internet search of symptoms, seek health care),
   iii. data record capture,
   iv. transfer data to SyS system,
   v. application of detection algorithms, or
   i. generation of automated alerts.

   Data transfer lags can occur at any of these junctures, causing changes to timeliness.

4. **Data quality** measures include completeness (e.g., blanks or missing data elements), accuracy (e.g., mistakes in recording information), and representativeness (e.g., is the data representative of the population?).

Data source identification is discussed again in *CASE STUDY: Augmenting Syndromic Surveillance for Real-Time Situational Awareness During Extreme Heat Events in Ottawa, Canada*.

2 System Architecture

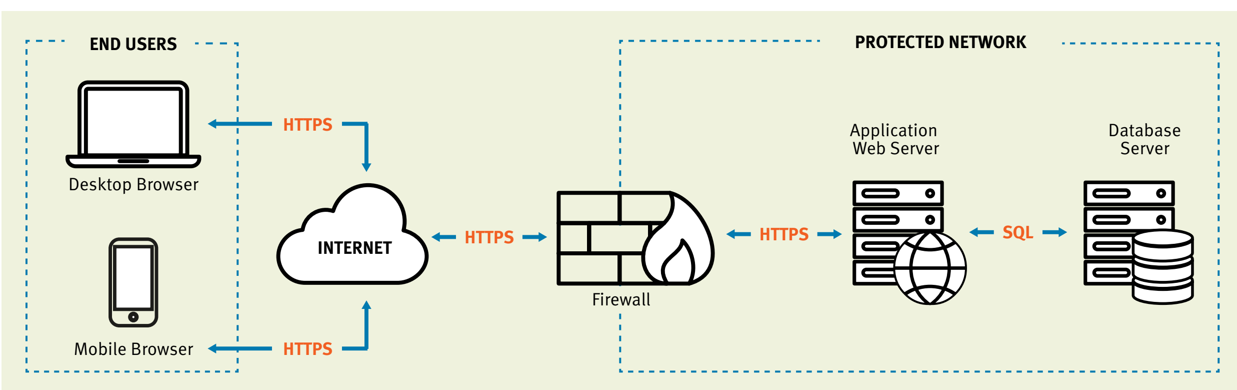
System architecturpe describes the technical framework of the various computer components in the system, such as the hardware, software and networks needed for all system functions. Architecture design needs to account for security, user authentication, data input and integration, data transfer, and statistical packages and/or algorithm-support applications. A simple schematic is shown in Figure 8; data are input via an Internet-connected browser and then transferred to a protected network using a web application to a centralized computer system, and transferred to a database for storage. The web application would include the capacity to display and manipulate the data, as well as permit user-defined and/or built-in aberration detection techniques for alerting procedures (see section *4. Alerting Protocols*). A detailed discussion of system architecture is found in a report published by the ISDS, *Architectures and Transport Mechanisms for Health Information Interchange of Clinical EHR Data for Syndromic Surveillance* (Arzt 2012).

For SyS systems that integrate meteorological information with health outcome data, data display is achieved using GIS methods that support several layers of information and are updated in real or (near-real) time. For example, SUPREME monitors nurse advice calls, acute care visits, and ambulance visits for the province of Quebec, and can monitor both meteorological variables and health outcomes at the same time. The system architecture for SUPREME is shown in Figure 9. Note the multiple data sources (meteorological, air quality, health, demographic, and geospatial) are all separately collected into a system that acquires and integrates the datasets into a common platform for subsequent analyses. The four main components of the SUPREME architecture include:

1. data acquisition and integration (F1) that pulls the data from all the data sources to be integrated,
2. risk analysis and alerts (F2) where automated statistical processes calculate background counts and aberrations for alerting processes through email and short message service (SMS, or texting) to stakeholders,
3. cartographic application that enables map-based data visualization (F3), and
4. access to climate change and health information (F4).

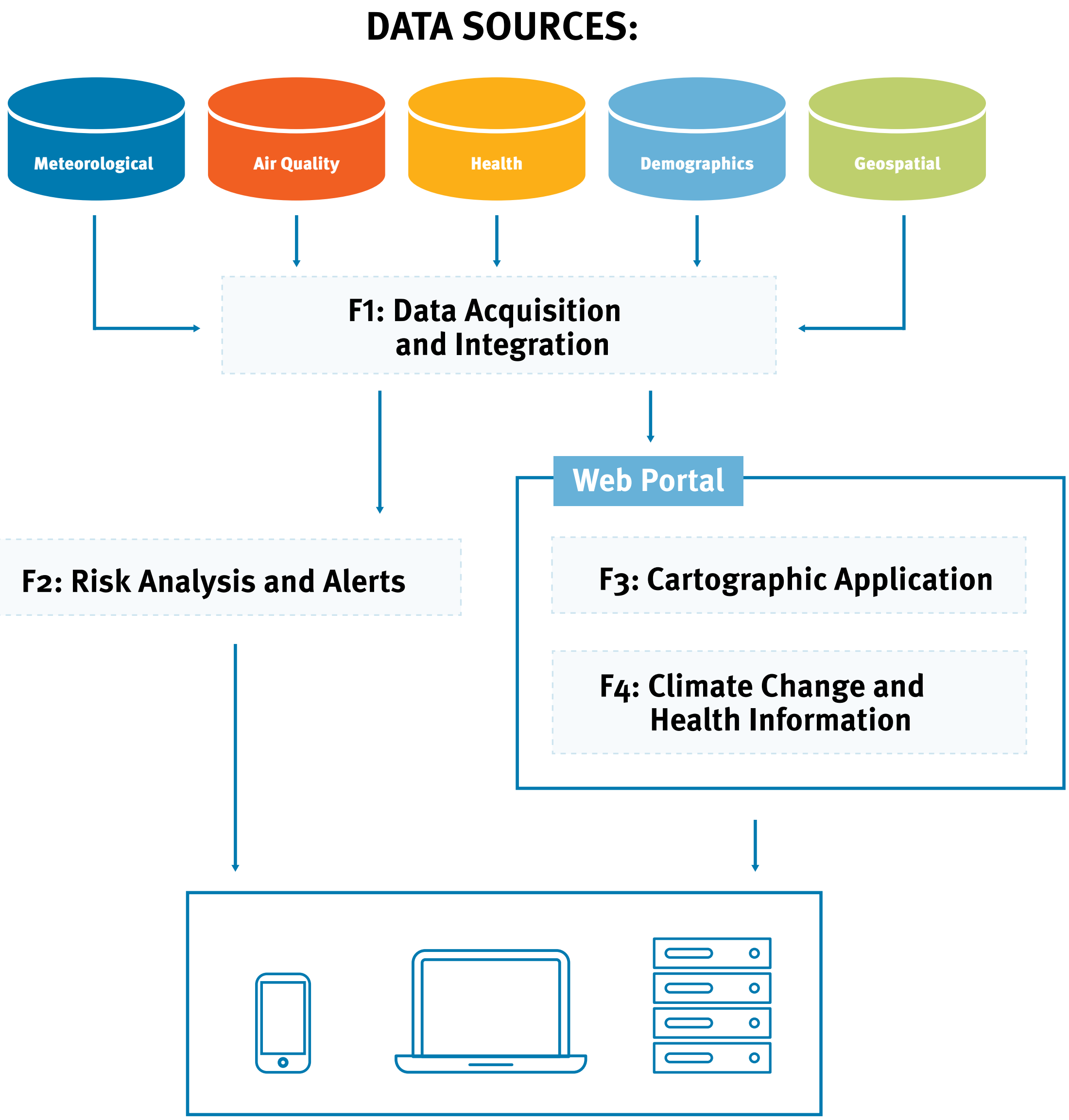
The components F3 and F4 comprise the public-facing web portal that enables users to display and interpret data. SUPREME is based on open source software framework in response to both cost and data-sharing concerns (Toutant et al. 2011).

Figure 8. Basic components of syndromic surveillance system architecture



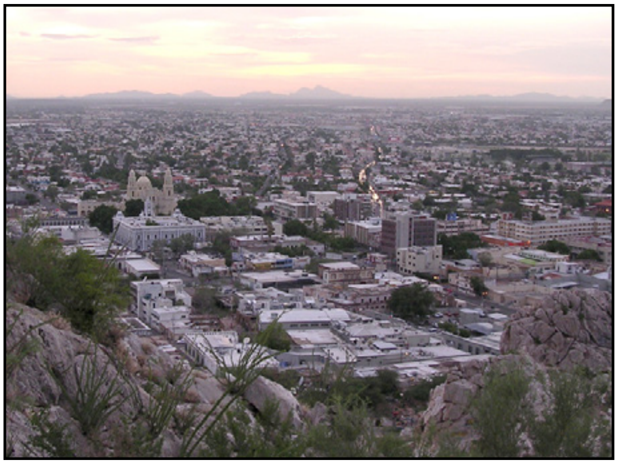
Source: Knowledge Management, KFL&A Public Health 2016

Figure 9. SUPREME architecture



Source: Toutant et al. 2011

Case Studies



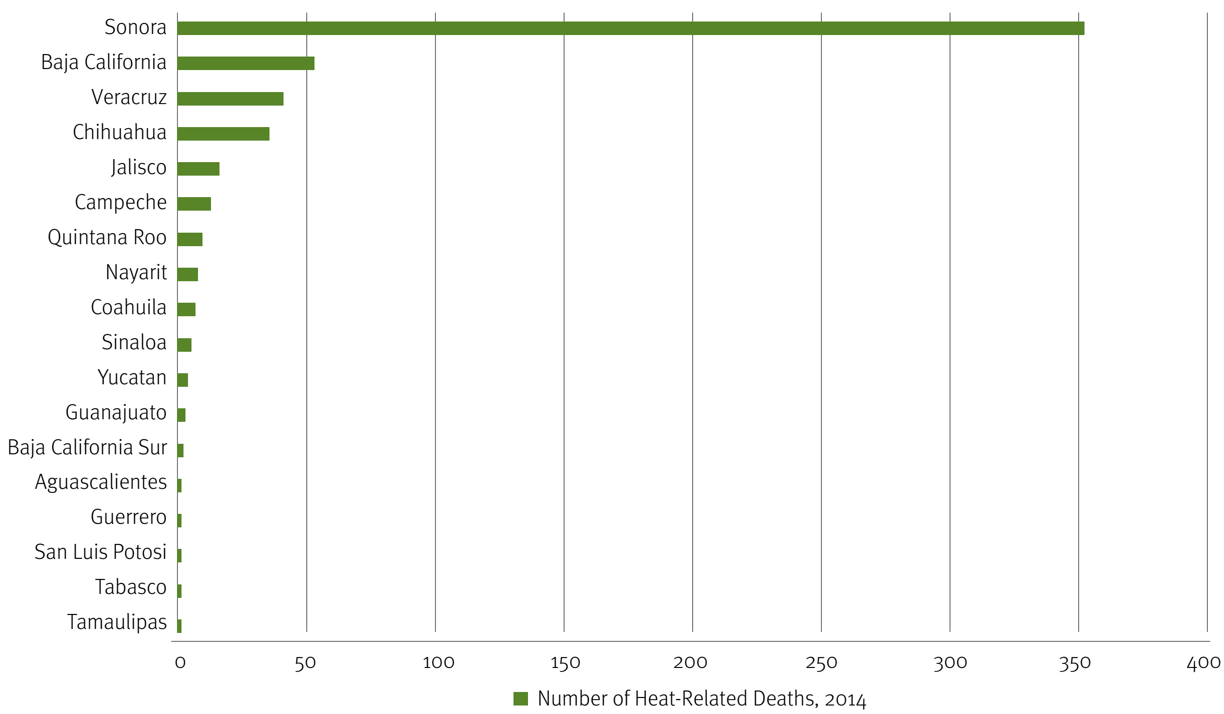
CASE STUDY: Hermosillo, Mexico, Captures Heat-Related Illnesses at Medical Facilities Using New Database

The Problem:

The threat of climate change in the state of Sonora raises serious concerns regarding the protection of human health, as daily maximum temperatures over 44°C are often recorded and conditions are expected to worsen. Sonora State has a desert climate, characterized by low precipitation, high sun exposure, and extreme heat. Approximately 60 percent of all heat mortality observed in Mexico for 2015 occurred in that state (Figure 10).

The high rates of mortality prompted all levels of government and health authorities to support measures to protect and prevent heat exposure in the region. Although reportable diseases are included in routine epidemiological surveillance in the region, information on HRI is not collated nor reported to central health authorities. Furthermore, electronic medical records are collected in hospitals or other medical facilities in Hermosillo, the capital city of Sonora, but for epidemiological analyses, paper records prevail.

Figure 10. Mortality due to extreme heat in Mexican states for 2015



Source: *Sistema de Vigilancia Epidemiológica en México, 2015*

The Solution

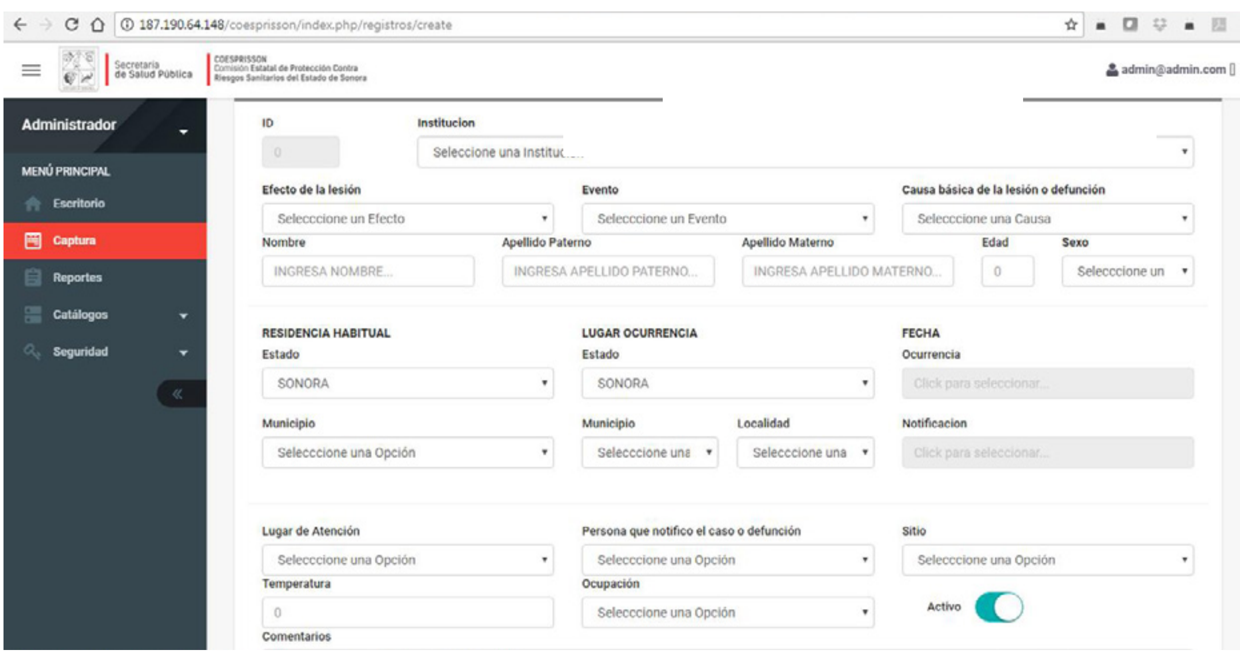
Working with Cofepris, the Ministry of Health, and the CEC, Sonora's regional health authority (*Comisión Estatal de Protección contra Riesgos Sanitarios del Estado de Sonora*—Coesprisson) established several objectives with the goal of creating a real-time SyS system for the city of Hermosillo in a 2016 pilot SyS project that would enable timely identification of health impacts due to extreme temperature and evidence-based policy development to reduce mortality and morbidity rates. These objectives included the following:

- conducting an analysis of HRI rates in the region,
- designing and implementing a computerized platform to receive and store real-time data related to the health effects and correlating these data with climate and demographic information,
- promoting coordinated work by data owners (i.e., meteorology and health), and
- implementing coordinated measures for health protection and prevention strategy during extreme heat events.

The common occurrence of extreme heat in this region makes it difficult to generate adherence to protective measures for extreme heat; messaging needs to be targeted to the most vulnerable populations to reduce "alert fatigue."

Four main presenting HRI were identified by the medical facilities in Hermosillo: (1) dehydration, (2) heat exhaustion, (3) sunstroke and (4) sunburn. The causes of the heat exposure in most of the cases identified were attributed to occupational exposures (e.g., farm and mine workers). The existing epidemiological surveillance consisted of weekly bulletins provided by local medical facilities of reportable diseases, but Coesprisson wanted to design a real-time system that included SyS of HRI. The team approached the problem by hiring six staff (two medical students, three nurses, and one paramedic) to be employed within two Hermosillo hospitals to actively seek out HRI cases and record their details into a newly constructed database (Figure 11). Using appropriate security and privacy features, the team established the basis of a heat-specific SyS system that was implemented in the two hospitals, and can be expanded to more hospitals and/or health outcomes as resources permit. For

Figure 11. The dashboard for Hermosillo's syndromic surveillance for heat-related illnesses



Source: Hugo Medina 2016

example, one measure to protect data security and patient privacy allows only system administrators access to all medical records; staff that input data have access to records only as they are entered into the database.

The SyS system aims to collect information regarding both case details and the causes of the HRI. Data are collected in real time for HRI cases, including the following data elements:

- reporting medical facility,
- address of medical facility,
- effect of injury (i.e., illnesses or death),
- basic cause of injury/death (i.e., dehydration, heat exhaustion, heat stroke, sunburn),
- demographic information (patient name, age, sex, address of residence)
- address of exposure/incident,
- date of exposure/date of notification,
- name of staff member reporting case,
- SyS study site,
- environmental temperature at time of exposure, and
- date and time of information capture.

At present, temperature is entered into the database at the same time as patient information, but automatic weather information input is being pursued with the collaboration of Mexico's meteorological system.

Lessons Learned

One of the main challenges faced by Coesprisson in their pilot project was the issue of alert fatigue. The community is used to daily life in a consistently hot environment, and lives with the daily risk of exposure to extreme temperatures. Education strategies and the implementation of policies for different sectors (e.g., workplaces, schools, etc.) that are sensitive to the adaptive capacities of each specific sector need to be developed in coordination with the at-risk populations. Such collaborative policy development should ensure that messaging and adaptive strategies are appropriate to the population they target. For example, the initial data from this project indicate that most HRI are due to occupational exposures. Prevention and protective strategies need to include input from employers, workers, and occupational health authorities. Safety specialists could be put in place for specific occupational sectors to ensure that policies and education strategies are properly implemented and effective. The data collected with the SyS system in Hermosillo should be used to demonstrate the increased risk experienced by certain local occupational groups to create protective policy. Data collected during the 2016 pilot project indicate that the typical patient for HRI presenting at the participating medical facilities was a male (42 of 58 cases), exposed to extreme heat at work (35 of 58 cases) or dehydration (44 of 58 cases).

There are often circumstances where electronic data sources are unavailable and researchers need to create opportunities to collect the information. In Hermosillo, the database created by Coesprisson to collect HRI information allows researchers and public health authorities to analyze and display health outcomes in near-real time in a circumstance where electronic medical records are not readily available for this purpose. This system is an example of active surveillance, where the accuracy and effectiveness of the system are dependent upon the input practices of the staff responsible for reporting the HRI cases. Additional staff would be required to expand the pilot SyS to other medical facilities, as well as additional staff training and enhancements to the current database to support multiple simultaneous users. It is possible that further simplification of the application to run on operating systems for cell phones and tablet-based technologies could be employed to enhance the pilot SyS reporting protocols. This SyS system could easily be expanded to other reportable HRI, as well to other syndromes of medical interest (e.g., occupational injury, chemical exposures), thereby increasing the value of this database to public health surveillance strategies in Hermosillo.

3 Defining a Heat Syndrome

The pre-diagnostic data collected from the various sources must be processed and classified into medically relevant syndromes in order to derive epidemiological information. To generate syndromic groupings, the electronic record needs to be analyzed and classified using a statistical syndrome classifier; the classifier chosen depends on the data that is used. For example, if the SyS system is based on free-text chief complaints from acute care records, the classifier will be based on groupings of keywords and/or phrases. If the data consist of pre-diagnostic codes, the classifier will be based on those specific codes or groups of codes. This is relevant for SyS systems using data from hospitals that employ drop-down, pre-defined coding for recording the reason for hospital visits instead of free-text chief complaints.

Different approaches are taken by different SyS systems to define syndromes. Some are based on machine learning and natural language processing (NLP) techniques, where classification algorithms are applied to textual data to effectively teach the system to correctly classify words and phrases (or codes) into groupings of medical interest. Like a spam detector operating in an email application, a syndrome classifier can recognize text in a healthcare record that has varying probabilities of being related to specific symptoms, which can in turn indicate certain medical conditions (or syndromes). To allow the system to recognize the various syndromes of interest, the system needs to be tested with a large dataset consisting of healthcare records of known disposition. For a detailed description of these processes, various approaches are described in *Using chief complaints for syndromic surveillance: A review of chief complaint-based classifiers in North America* (Conway, Dowling, and Chapman 2013).

Applying these methods to HRI poses challenges; the etiology of HRI are generally not specific, and presenting symptoms may be misinterpreted and/or misclassified into other syndromes. Several approaches to this problem are available: for example, some systems may classify a single record into several different syndromes, and priority could be given to an HRI syndrome when temperatures are above predetermined thresholds. The approach used depends on the goals of the SyS system, as well as the quality of the data sources. The Michigan case study illustrates both the methodology and the challenges of defining a heat syndrome to capture HRI.

CASE STUDY:
Enhancing Syndromic Surveillance for Heat-Related Illness in Michigan with Improved Heat Syndrome Definition

The Problem

The MSSS tracks chief complaints in real time from acute care facilities (i.e., 103 hospital emergency departments and six urgent care clinics) in the state of Michigan. The system enables SyS monitoring of symptom trends for public health threats that could present in the community and require interventions. Epidemiologists from the Michigan Department of Health and Human Services (MDHHS) receive real-time alerts of unusual symptom presentation from MSSS; staff then verify these alerts and contact local public health agencies and other healthcare stakeholders, if warranted, to permit implementation of preventative and protective actions. MSSS employs the healthcare industry standard Health Level 7 (HL7) data format for the transfer of information. Data elements received from the various healthcare facilities include patient information (e.g., age, sex), visit information (e.g., time, date), and chief complaint.

MSSS is based on an open-source software package from the University of Pittsburgh's Real-time Outbreak and Disease Surveillance (RODS) system. Syndrome classification for each emergency department record is carried out by the system according to the chief complaint into one of nine syndromes using an algorithm based on keywords. The algorithm, Complaint Coder, is a Bayesian classifier that categorizes data by matching key phrases into one of nine predefined syndromes. A "Default" syndrome receives the records that cannot be assigned. The syndromes and a sample of keywords used for the classification are shown in Table 5. Briefly, the nine syndromes are (1) gastrointestinal, (2) constitutional, (3) respiratory, (4) rash, (5) hemorrhagic, (6) botulinic, (7) neurological, (8) other, and (9) default.

With no specific syndrome for HRI, *ad hoc* keyword searches could be made for words related to HRI, but these would not be in real time to provide the situational awareness during an extreme heat event, nor have automated alerting capabilities if higher than expected visit counts occur. With the goal to support the development of population heat resiliency and the capacity to withstand the effects of climate change, MDHHS and the CEC partnered to improve the MSSS to include a HRI-specific syndrome.

The Solution

The new syndrome is called *Heat* to reflect that it is triggered by only heat-related (i.e., not cold or other "seasonal") keywords in chief complaints. A list of one- and two-word inclusion keywords were developed. Exclusion terms were also developed to assist the classifying algorithm; classification results were improved using these exclusion terms as keywords for the *Other* syndrome, rather than as exclusion terms for *Heat*. The exclusion terms are: attack, flash, palpitations, rate, racing, flashes, pad, pack, and vent. Eliminating these terms assist in providing good quality data by distinguishing misspelling of "heart" as "heat" (e.g., "heat attack"), remove "heat flash(es)", and burns from heat pads, packs, and vents from the *Heat* syndrome.

The final *Heat* syndrome includes 36 keyword terms (including misspellings), as follows:

Table 5. Keywords for syndromes in the Michigan Syndromic Surveillance System

Syndrome	Keywords
Gastrointestinal	abdominal, stomach, epigastric, gastric, gastritis, enteritis, appendicitis, diarrhea, vomiting, vomitting, nausea, n, v, rlq, abdomen, abd, crohns, gerd, diverticulitis, gastroenteritis, emesis, hyperemesis, poisoning, pud, peptic, ruq, llq, luq, nv, nvd
Constitutional	fever, weakness, dizziness, dizzy, temp, flu, lightheaded, chills, lethargy, fatigue, weak, sweating, lethargic, febrile
Respiratory	cough, ribs, breath, wheezing, croup, pharyngitis, respiratory, thrt, st, congestion, shortness, rib, strep, throat, cold, bronchitis, pneumonia, copd, asthma, sob, tonsillitis, breathing, sinus, sinusitis, uri, dyspnea, resp, dib, pneumonitis, pleural, pleurisy, airway, sorethroat, coughing, congested
Rash	rash, urticaria, hives, bumps, petechiae, purpura, ivy, dermatitis, pox, scabies, spots,
Hemorrhagic	epistaxis, bleeding, hemoptysis, hematuria, hematemesis, blood, bleed, hematochesia, hemorrhagic, hemorrhaging
Botulinic	slurred, diplopia, dysphagia, photophobia, dysarthria, speaking, swallowing, blurred
Neurological	migraines, memory, headpain, migrane, migrain, disoriented, disorientation, passed, syncopal, palsy, fainting, paralysis, tingling, seizures, headaches, cephalgia, stroke, tia, cva, ha, headache, migraine, seizure, convulsion, syncope, fainted, loc, mental, vertigo, meningitis, numbness, numb, h, confused, confusion, dementia, unresponsive, dizziness, unconscious, dizzy
Other	lac, mva, laceration, cnt, contusion, contusions, fx, broken, sprain, bee, injury, inj, mvc, bite, fb, abrasion, wound, suture, crisis, injured, doi, concussion, physical, pe, sunburn, pressure, fall, sugar, gsw, fell, monoxide
Default	everything else (default category)

Source: Altarum Institute 2016

dehydration, dehydrated, dehydrate, dehydrat, dehydraton, heat, heatstroke, overheating, overheated, heating, heated, sun, sunburn, sunburnt, sunburned, hyperthermia, sunstroke, heat rash, heat exhaustion, heat stroke, over heated, heat exposure, heat related, heat exhaust, over heating, heat cramps, heat illness, heat issues, heat bumps, sun burn, sun poisoning, sun burned, sun blisters, sun reaction, heat syncope, heat fatigue

MSSS uses a weighting technique to estimate the relative importance of the various keywords to assist the algorithm in sorting between possible syndromes. Initial weightings of the keywords were tested and refined twice during the project to fine-tune the resulting classifications. For example, dehydration is a symptom for a number of different medical conditions; after reviewing initial results, MDHHS decided to keep dehydration-related keywords in the *Heat* syndrome, but changed its weighting from 0.05 to 0.02 to reduce misclassification.

To determine exceedances above expected counts, MSSS developed alerting rules for the *Heat* syndrome. MSSS calculates baselines for the other syndromes as the mean of the previous 120 days; exceedances are considered counts for one day that are more than one standard deviation greater than the 120-day mean. This type of baseline calculation does not work for the *Heat* syndrome due to seasonal changes in temperature; for example, this method would compare June counts to a baseline calculated from February through May acute care visits. Instead, a baseline was determined from multiple years of historical data for each Michigan county and for the state as a whole. MSSS uses its alerting algorithms to notify public health staff when heat-related visits exceed the calculated baselines, both statewide and by individual counties, as it does for all other syndromes.

Lessons Learned

The key lessons learned by the MDHHS as they defined the new syndrome, *Heat*, to monitor HRI include the following:

- methods were developed that can be applied to other RODS-based SyS systems to bypass the built-in limits to the number of syndromes that can be simultaneously analyzed,
- methods to use exclusion terms to assist in classifying a new syndrome were created, and
- a solution to establishing baselines for seasonal syndromes was established.

The final lesson was learned as MDHHS explored the challenge presented by seasonal syndromes to calculate meaningful baselines; data from the same time period from previous years will be used to compare current counts and apply aberration detection.

4 Alerting Rules

The aim of SyS is to identify unusual disease (or health condition) clusters through the early detection based on pre-diagnostic data that otherwise would not be detectable using traditional surveillance methods. These clusters, or aberrations from expected baseline counts, occur when one count (i.e., totals for one day, or other predefined time period) exceeds a certain value or behaves in a way that is not likely to have occurred by chance alone. Alerting rules vary amongst SyS systems and different rules may be applied to different syndromes within the same system (for example, MSSS uses different rules for *Heat* than for other syndromes). Examples of alerting methods include the following:

- basic "eyeball" of the daily data (generally accurate only for analysts very familiar with the data);
- statistical deviation from baselines calculated using predefined timeframes (e.g., 120 day);
- statistical deviation from baselines calculated from the same timeframes in previous years or from previous events (i.e., historical baseline); and,
- algorithms based on other threshold-based methods (e.g., CuSum, see below).

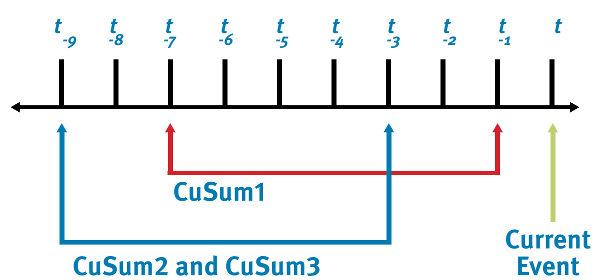
The statistical deviation methods are discussed in the MSSS Case Study. The Cumulative Sum (CuSum) family of alerts are based on algorithms developed by the CDC's Early Aberration Reporting System (EARS) in early versions of the ESSENCE/BioSense Platform, and is used by a wide range of health authorities across the United States and Canada. EARS was designed to detect anomalous events around a discrete event (e.g., Olympic Games) for which very little background data exists; baselines can be calculated using just seven days of counts. Three EARS algorithms are defined with varying sensitivity: CuSum1 bases its aberration detection on the previous seven days of data, CuSum2 and CuSum3 move the baseline calculation to the seven days prior to CuSum1's baseline (Figure 12). For more information regarding alerting rules and practices, the ISDS has compiled a list of several resources that describe cases studies including specific alerting protocols (www.syndromic.org/resources).

Not all aberrational counts warrant an alert to be issued to public health authorities. Response protocols to alerts need to be clearly defined to ensure the appropriate action is taken. Response protocols include the alerting rules and accepted exceptions for each syndrome; the roles and responsibilities of the staff involved in the response, including a notification list; and the actions to be taken for an alert. Response protocols should be regularly tested and updated to reflect changes in the population and resource availability.

The ISDS have produced an online training course, *Syndromic Surveillance 101*, with a module that outlines key steps in an effective response protocol (International Society for Disease Surveillance 2007b). Briefly, an example of response protocol is shown in Figure 13. In this example, a data analyst is the first responder to the alert. They need to evaluate the anomaly according to what is expected, and with thought to what events may be occurring in the area to cause the anomaly. It is also possible to validate the alert by checking other data sources, or if similar events are occurring in neighboring areas. The next decision then needs to be made regarding the level of response, as follows:

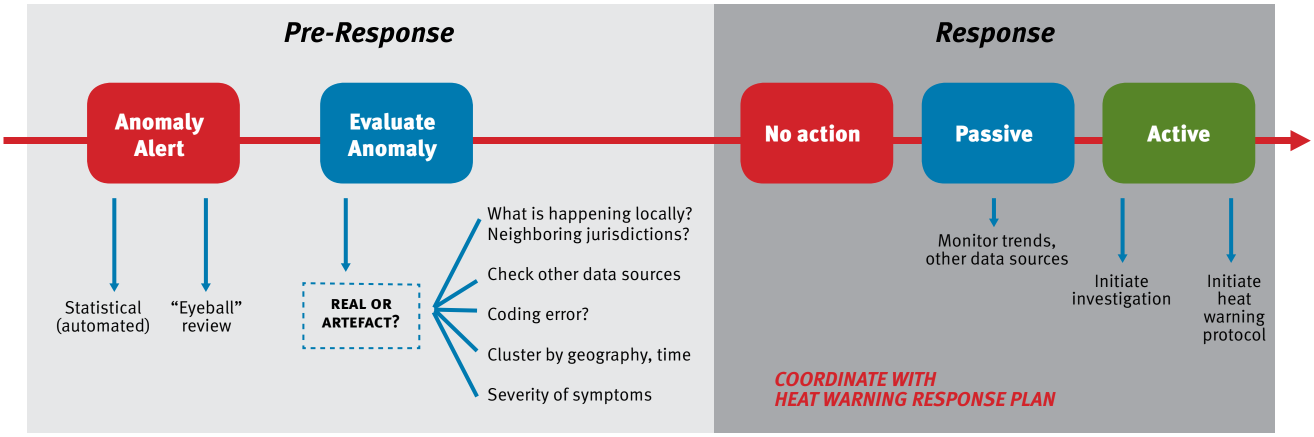
- no response, if the anomaly is not considered a threat;
- passive response, if the public health threat is considered minimal or of low risk the analyst may decide to continue to monitor the situation; and,
- active response, if the anomaly is considered a public health risk an investigation of the outbreak and/or the communication plan will be initiated.

Figure 12. Timelines for Baseline Calculations for Cumulative Sum (CuSum) 1, 2, and 3 Alerting Rules



Source: Knowledge Management 2013

Figure 13. Timeline for Anomaly Alert Response Protocol



Source: International Society for Disease Surveillance 2007b

Alert response protocols for HRI need to be informed by heat warnings derived from meteorological data, as discussed in the previous section, *Using SyS to Assist Public Health Response*. Alerts for HRI-related syndromes are unlikely to occur in the absence of hot weather conditions; an anomaly detected under these conditions likely warrants an evaluation of the SyS system. It is important to note that this may not be true in hot climates. For example, in the state of Sonora, HRI occur regularly even in non-alert conditions. Regardless, a syndrome alert and/or its severity can give valuable information to public health authorities during an extreme heat event; the alert can, for example:

- provide evidence to identify vulnerable populations (or neighborhoods),
- geospatially locate vulnerable populations for resource allocation,
- provide evidence for the effectiveness of risk communication strategies, and
- provide evidence for the severity of health response to the heat exposure.

The absence of an alert during an extreme heat event can provide information about the sensitivity of extreme heat warning protocols (including thresholds, education, and communication strategies) that may need to be re-evaluated. HRI-related syndrome alerts should always be considered in association with meteorological conditions.

5 Integrating Health Outcomes and Weather Information

An ideal SyS for HRI combines the extreme heat warning protocols and situational awareness of meteorological conditions, as discussed previously, with the statistical monitoring of health outcomes using SyS. The SUPREME system used in the Province of Quebec, Canada, SUPREME integrates information from meteorological, air quality, health, demographic, and geospatial data sources for risk analysis and map-based data visualization in real time (see section *2 System Architecture*, and Figure 9). The objectives for SUPREME provide a standard framework for new systems to follow, as outlined below (Toutant et al. 2011):

- to provide a map-based representation of meteorological conditions, including real-time measures, alerts, and forecasts;
- to provide geospatial description of heat-vulnerable populations;
- to provide map-based population health status indicators, such as air quality parameters, forecasts for extreme heat events; and
- to provide map-based health outcome indicators in order to (1) support situational awareness for launching public health action, and (2) retrospective evaluation of the health impacts of extreme heat events.

CASE STUDY:
Augmenting Syndromic Surveillance for Real-time Situational Awareness During Extreme Heat Events in Ottawa, Canada

The Problem

The city of Ottawa has a humid continental climate, characterized by four distinct seasons with large temperature variations; summers are typically warm and humid, and winters are cold with enduring snowpack. Cities in northern climates face particular threat from extreme heat events: severe health effects may occur due to limited acclimation and adaptation. Ottawa Public Health (OPH) monitors the health effects of extreme heat using the Acute Care Enhanced Surveillance (ACES) system; in addition to providing the province with SyS based on triage data from over 80 percent of Ontario's acute care hospitals, ACES displays regionally specific data for the city of Ottawa from its five participating hospitals. ACES uses NLP methods to classify free text chief complaint information in real time into approximately 80 syndromes; the *Enviro* syndrome for HRI captures keywords and phrases that are directly related to HRI, such as dehydration, sun exposure, sunburn, heat syncope, and heat stroke. The *Enviro* syndrome is retrospectively validated against heat-related diagnostic codes from the same acute care facilities.

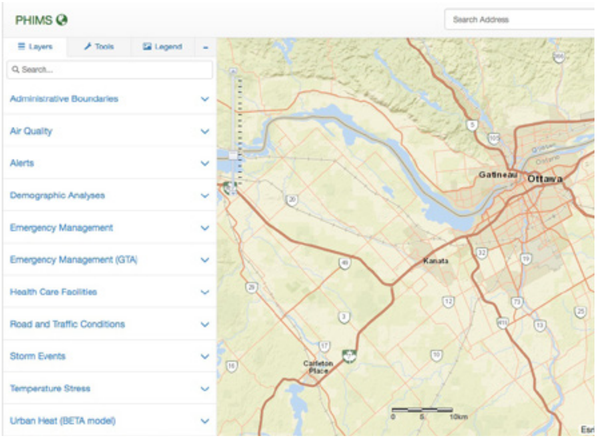
The city of Ottawa has made adaptation to climate change a public health priority. In collaboration with the CEC and HC, OPH seek to improve its understanding of the HRI and its capacity to protect the most vulnerable residents by increasing the sensitivity of the *Enviro* syndrome and enabling the integration of weather and health outcomes data sources for real-time situational awareness.

The Solution

To improve the sensitivity of ACES, new data sources were pursued that may be able to provide pre-diagnostic data earlier than the triage data currently used (e.g., see Figure 1); specifically, a data sharing agreement was negotiated with Telehealth Ontario, a nurse advice telephone service. Phone call records to Telehealth nurses may represent an earlier, and possibly larger, dataset for HRI than hospital triage data. Positive data characteristics, such as suitability, availability, timeliness, and quality, make this new data ideal to support trends observed in existing data, and possibly improve the timeliness of the system for HRI. Other data sources that were pursued (and may be included at a later date) were ambulance dispatch records, and various social media and news sources.

To integrate the health outcome data with weather data, a situational awareness tool, the Public Health Information Management System (PHIMS), has been restructured for use by OPH. The new system is called the Ottawa Syndromic Surveillance for Extreme Heat (OSSEH). PHIMS provides a web- and map-based display of both real-time and static data of relevance to emergency management and public health. Figure 14 shows the main screen of PHIMS with the right-hand menu showing the various categories of information that can presently be displayed. Data sources that are already displayed in PHIMS, and the additional data sources added for OSSEH are shown in Table 6. Data available in the system range from static information, such as the administrative boundaries of the city of Ottawa and the local public health authority, and postal codes divisions, to the display of data

Figure 14. Main Page of Public Health Information Management System



Source: www.phims.ca. Knowledge Management 2016.

that are updated in real-time (e.g., health outcomes, temperature, air quality parameters). For OSSEH, no changes were made to the acute care triage data collection protocol, nor were there changes to the NLP algorithms used to create the *Enviro* syndrome. The populations in Ontario most vulnerable to heat are older adults and children, new immigrants, outdoor workers and people who exercise outdoors, as well as the socially isolated and materially deprived (Bassil and Cole 2010; Harlan et al. 2013); vulnerability measures for them can be assessed using the demographic data available from census data collected by Statistics Canada. Deprivation indices are calculated from demographic data from the national census aggregated by postal code as a proxy for socioeconomic status (Pampalon et al. 2009).

One challenge for the OSSEH was displaying within the parameters of privacy parameters the health outcome data that were to be kept. Health outcomes from ACES are displayed as aggregated and anonymized means for specific geographic/administrative boundaries (i.e., local public health agencies and forward sortation area, or the geography defined by the first three digits of postal codes). The Telehealth data are transferred-in as anonymized data elements; the data are displayed as counts for the calls, sorted as *Heat*-related.

Several relevant parameters related to the thermal loading and transfer of heat in the built and natural environment can be derived from satellite imagery. Open source Landsat 8 satellite imagery (source: NASA) will be processed to define the local areas of possible increased heat stress. Normalized Difference Vegetation Index (NDVI) is one such source of information derived from satellite imagery, and is an estimate of the relative amount of vegetation. In combination with land surface temperature, NDVI can be used to define areas that may represent localized regional hotspots. Within cities, these areas tend to be highly built environments with minimal vegetation and impermeable surfaces. The urban "heat island effect" describes the characteristic excess heat of urban areas in comparison to rural. Understanding regional variation in temperature in relation to residential patterns is essential for determining the potential impact of heat, particularly for vulnerable population with limited access to air conditioning and substandard residential building materials.

Table 6. Data sources for the Ottawa Syndromic Surveillance for Extreme Heat system

Data Source	Source	Data Type	Details
acute care triage	ACES	health outcomes	data elements include time and date, age, sex, chief complaint free text, acuity, disposition
air quality parameters from local monitoring stations	ECCC	geophysical	data elements include AQHI ($PM_{2.5}$, O_3, NO); NO_2, PM_{10}, SO_2
demographic data	Statistics Canada	forecast	proxies for Socioeconomic status derived from census data
weather data from local meteorological stations	ECCC	geophysical	data elements include air temperature at hourly and daily intervals, humidity, humidex, precipitation volumes, wind direction and speed
weather warnings	ECCC	forecast	geospatial information and text details
Additional data sources:			
nurse advice line calls	Telehealth Ontario	health outcomes	Telehealth's Heat syndrome: data elements include time and date, age, sex
OPH heat warning	OPH	forecast	region-specific warnings
satellite imagery	NASA, KM	geophysical	static images of surface temperature, green space

Source: Knowledge Management 2016

The OSSEH provides a real-time situational awareness and decision-making tool for the City of Ottawa. The multiple data sources displayed together allow public health staff to visualize the various data during an event; at present, analytics to derive metrics, such as the relationship between temperature and health outcomes in real-time, could be made possible in this platform. In its present form, the OSSEH provides the city of Ottawa with an integrated, map-based tool that provides improved situational awareness to assist resource allocation for public health action and the capacity to conduct post event evaluation of the health impacts of extreme heat.

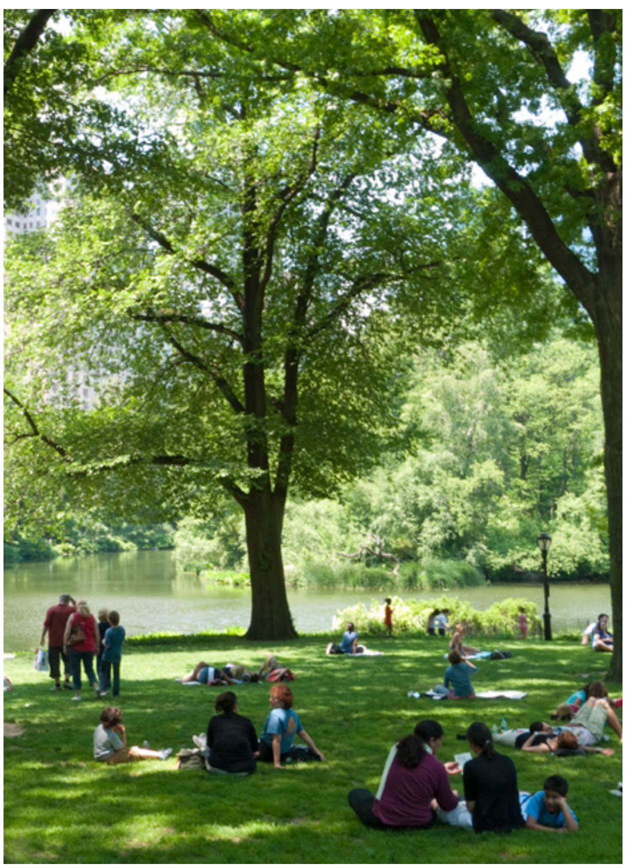
Lessons Learned

One of the greatest challenges for a SyS system like the OSSEH is associated with the uptake of new technologies. The OSSEH provides a wealth of information that can influence public health decision-making at all levels, from assessments of vulnerability to evaluating the actions taken to reduce heat exposure during an extreme heat event. OPH will be providing webinars and training to relevant staff to improve the adoption of the OSSEH into assessment and triage tasks by front-line staff (i.e., Telehealth call attendants, triage nurses) to improve the recognition of HRI symptomology and treatment.

Conclusions

Strengths and Limitations of Syndromic Surveillance to Monitor Extreme Heat Events

The strengths and limitation of SyS for HRI are similar to those for SyS for other health outcomes, such as infectious diseases (e.g., seasonal influenza). SyS may provide an early indication in the change of population health status. If it is linked to demographic information, the information could yield valuable vulnerability information for public health agencies for outreach efforts. For the surveillance of a health outcome due to an environmental exposure, SyS enables real-time monitoring of the progression of the event. For extreme heat events, SyS, coupled with same-time monitoring of meteorological information, enables emergency management via situational awareness, information to assist resource allocation, and information to evaluate events and interventions.



SyS also needs to be understood in the context of traditional public health surveillance. Its purpose is not to replace traditional methods, such as diagnostic data from electronic medical records and laboratory reports, but to enhance these sources of information. A public health investigation of a SyS alert is not a clinical investigation; small outbreaks or isolated cases of disease are not the target applications of SyS.

Passive collection of pre-diagnostic data offers many benefits to collecting the diagnostic data associated with traditional public health surveillance: costs associated with acquiring data may be lower than setting up systems to collect the data, using multiple sources can improve the representativeness of the data for the population, and automated passive systems do not require additional work from healthcare providers. In contrast, pre-diagnostic data can be inconclusive regarding health outcomes and may not be representative of the true health effects in a population (e.g., if healthcare is inaccessible for a certain population, neither the population nor their health effects will be included in the data collection).

For the case studies presented herein, the implementation of SyS for HRI in each of the communities has highlighted the strengths and limitations for these systems. For all systems, SyS for HRI presents an opportunity to monitor the health effects of extreme heat that is otherwise not possible; each presents an improvement on the status quo surveillance in the communities. In all cases, there are limitations presented by the data that can be collected. For example, preliminary data from Hermosillo's SyS indicates that males between the ages of 18 and 65 are the most heat-vulnerable population, yet many people in other age groups are also at risk. Another limitation of SyS is that it does not collect information on the indirect effects of HRI (e.g., increased crime rates, increased drowning incidents, exacerbation of chronic health conditions, etc.). Methods to monitor indirect effects in real-time may assist in the identification of all heat-vulnerable populations; their etiology, however, make them difficult to distinguish those health outcomes exacerbated by extreme heat.

Summary of Lessons Learned

Five key steps are required to create a SyS system or to enhance an existing SyS system to monitor health outcomes related to extreme heat. They are:

1. identifying data sources, including the consideration of data suitability, availability, timeliness and quality,
2. defining system architecture in relation to resources and objectives,
3. implementing methods to define a syndrome for HRI,
4. using alerting rules to create meaningful system alerts, and
5. integrating health outcomes and meteorological information.

Case studies are presented for three pilot communities. Hermosillo, in the state of Sonora, Mexico provided a description of their development of a SyS system based on active surveillance of HRI in two acute care facilities. This case study is highlighted within the section regarding system architecture. As the United States pilot community, MSSS provides SyS for the state of Michigan; their experiences are described in the section outlining syndrome definition. Finally, the pilot community from Canada, the city of Ottawa is used to illustrate the integration of SyS and weather data.

The key lessons learned by the pilot communities are as follows:

- Identification of data sources, and careful collection of data sources are integral to creating a database for SyS.
- Working SyS systems can be built without electronic medical records, with active surveillance techniques.
- Data collected by SyS can be used to identify populations and/or geographic regions that are vulnerable to extreme heat.
- In communities where occupational exposure to heat is an important cause of HRI, messaging strategies should be developed in coordination with employers, workers and occupational health authorities.
- For SyS systems in hot climates, alert fatigue should be considered, with appropriate messaging strategies to increase information uptake.
- Messaging could be coordinated with aberration detection to improve uptake and reduce risks.
- RODS-based systems with fixed methods for syndrome definitions can be modified to accommodate greater numbers of syndromes.
- Likewise, new syndromes can be defined in RODS-based SyS systems.
- Creative statistical methods should be employed to establish baselines for sporadic seasonal events such as extreme heat in temperate climates.
- For SyS systems that integrate meteorological and health outcomes information, training of system users is integral to the uptake of the technology.
- Further work that defines statistical relationships between heat and health is needed to develop health or weather indicators (or a combined metric) in order to improve heat response plans and emergency protocols.

Resources

ACES (https://aces.kflaphi.ca/#/)

CSTE Heat Guidance Document (http://c.ymcdn.com/sites/www.cste.org/resource/resmgr/pdfs/pdfs2/CSTE_Heat_Syndrome_Case_Defi.pdf)

CDC Public Health Information Network messaging guides (http://ww.cdc.gov/phin/resources/phinguides.html)

ESSENCE/BioSense Platform (http://www.cdc.gov/nssp/biosense/)

HL7 Implementation Guide (http://www.hl7.org/implement/standards/product_brief.cfm?product_id=398)

ISDS Syndromic Surveillance 101 Modules 1 to 4 (http://www.syndromic.org/resources)

Office of the Privacy Commissioner of Canada (https://www.priv.gc.ca/en)

OPH Heat Warnings (http://ottawa.ca/en/residents/public-health/hot-weather)

PHIMS (http://phims.ca/auth/login)

US Department of Health and Human Service's Health Information Privacy policies (http://www.hhs.gov/hipaa/).

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