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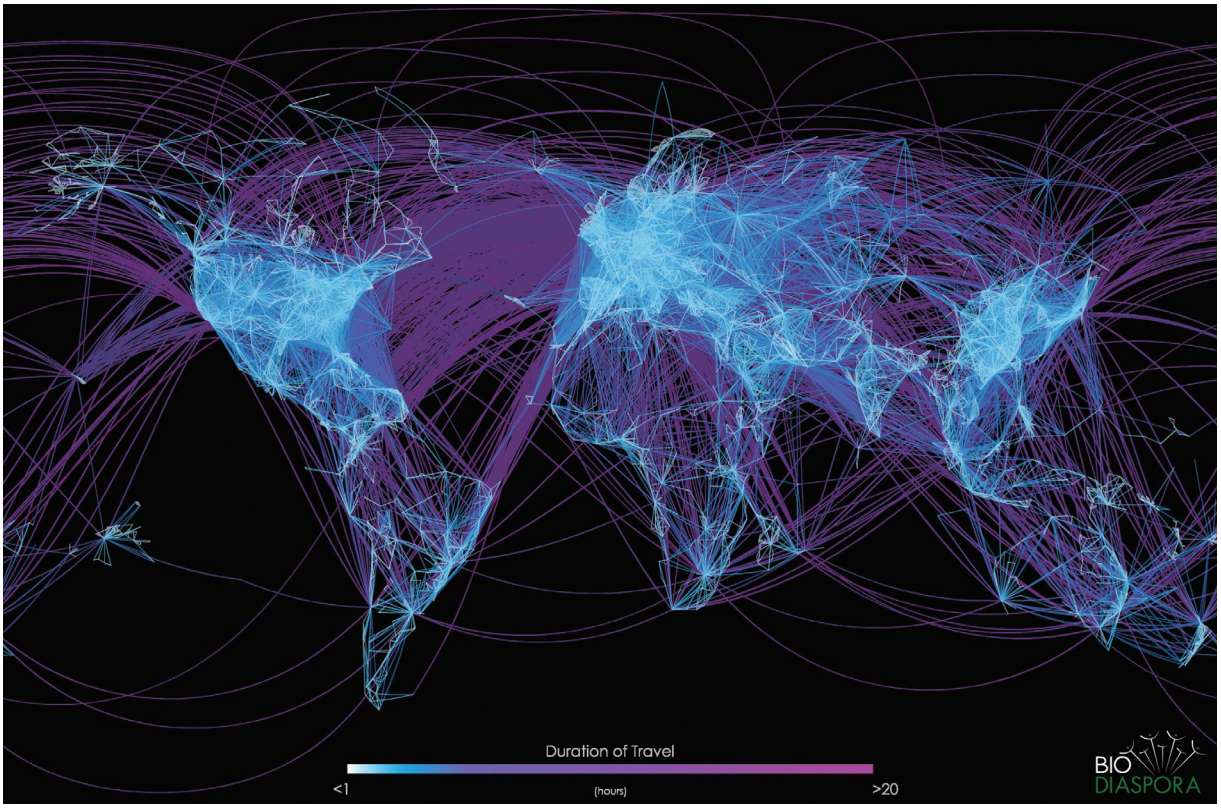
Scientists Use GIS to Thwart Epidemic Threats

Application Supports Preparedness at Global Events Including Olympics

"Real-time integration of web-based infectious disease surveillance, combined with knowledge of worldwide patterns of commercial air traffic, could significantly enhance global situational awareness of infectious disease threats."

Dr. Kamran Khan, St. Michael's Hospital, Toronto, Canada

With more than two billion passengers flowing through the global airline transportation network every year, once-localized infectious disease threats can now rapidly transform into worldwide epidemics, compromising global health, security, and prosperity. An innovative research team based at St. Michael's Hospital in Toronto, Ontario, Canada, is striving to prevent infectious disease outbreaks using a novel software platform—Bio.Diaspora—designed to assist in the rapid analysis of worldwide human population movement through commercial air travel and its association with the international spread of infectious diseases. Employing ArcGIS, this high-tech risk assessment platform has aided public health experts in countries around the world and was used to enhance public health preparedness for the 2012 Summer Olympic Games in London, England.



← The global airline transportation network is illustrated by the flight pathways of all commercial flights worldwide. This image shows the interconnectivity between cities and how easy it is for people—and diseases—to get from point A to point B in a matter of hours. St. Michael's Hospital medical geographer/cartographer David Kossowsky used Python, ArcGIS, and Photoshop to create the image.

Public health experts warn that mass gatherings such as the Olympics present potential health risks from communicable diseases not only to the host nation but also to the countries from which visiting athletes, spectators, and other travelers originate.

For instance, measles, one of the most highly contagious infectious diseases, was a notable risk at the UEFA, European Football Championships this year, as vaccination rates have dropped across Europe. In 2012 alone, more than 6,000 cases of measles have been reported in the Ukraine, a host country for the quadrennial soccer tournament. A measles outbreak after the Vancouver Olympics in February 2010 resulted in 82 confirmed cases, according to the British Columbia Center for Disease Control. Suboptimal vaccination coverage in the province contributed to transmission, the center reported at the time.

One public health expert who is vigilant in tracking the resurgence of infectious diseases is Dr. Kamran Khan of St. Michael's Hospital in Toronto, Canada. A practicing infectious disease physician and expert in globalization and infectious diseases, Khan and his research team developed and refined Bio.Diaspora, a first-of-its-kind interdisciplinary software system for rapidly generating evidence to support public health decision making for emergent global infectious disease threats. Combined with HealthMap, an online global disease mapping and tracking tool cofounded by Dr. John S. Brownstein of Boston Children's Hospital, Bio.Diaspora at last gives researchers a real-time system to support and enhance emergency preparedness and response capabilities during large-scale international events such as sporting competitions, religious pilgrimages, economic summits, and global expositions. The system integrates and synthesizes information across a number of scientific disciplines, among them the ability to understand how humans—and, consequently, human infectious diseases—move worldwide.

Urgent Need Born of Disaster

After Khan moved to Toronto in 2003, the local outbreak of SARS inspired him and his colleagues to develop new tools to improve pandemic preparedness and response capabilities on a global scale.

Despite the inevitability of future epidemics and pandemics like SARS and H1N1, research into the role of commercial air travel as a conduit for the spread of infectious disease has been limited. Most national and international pandemic influenza plans do not explicitly account for global patterns of air traffic and their implications on emergency preparedness and response strategies.

Literally meaning "scattering of life," Bio.Diaspora studies how infectious diseases are increasingly able to be dispersed worldwide through the movements of international travelers. A central feature of Bio.Diaspora involves understanding the global airline transportation network and leveraging knowledge of this complex "living" system to better prepare for—and respond to—infectious disease threats. To understand the interaction between global population mobility and infectious disease activity, Khan realized that GIS would be needed.

Early Successes Rewarded

Success came quickly. Bio.Diaspora accurately predicted how the H1N1 swine flu virus would spread worldwide via an analysis of more than 2.3 million international passenger departures from Mexico in early 2009. Published in the *New England Journal of Medicine*, the findings demonstrated that the international destinations of air travelers leaving Mexico were highly predictive of where cases of H1N1 first showed up around the world.

Bio.Diaspora was also used to assess global infectious disease threats during the 2010 Vancouver Winter Games, the World Cup, and the Hajj (the annual worldwide pilgrimage of millions of Muslims to Mecca), as well as infectious diseases around the world.

What is significant about this project is that it has led to the creation of a system that can rapidly integrate and analyze information about global infectious disease threats with numerous complementary data sources, including worldwide air traffic patterns. This capability allows countries to anticipate future events

and subsequently adopt proactive measures to prepare for an outbreak before it occurs.

Research findings from Bio.Diaspora's first report in 2009 were compiled into a 122-page document for the Public Health Agency of Canada entitled An Analysis of Canada's Vulnerability to Emerging Infectious Disease Threats via the Global Airline Transportation Network.

St. Michael's Hospital was selected as a 2011 laureate for innovation by the International Data Group's (IDG) Computerworld Honors Program. The annual award program honors visionary applications of information technology promoting positive social, economic, and educational change. Bio.Diaspora was selected from over 1,000 international entries, joining more than 250 others from 23 countries as winners in the 2011 program.

"Bio.Diaspora exemplifies the highest goal of GIS, which is to benefit society," said Alex Miller, president, Esri Canada Limited, of the accomplishment. "The system helps protect the health of the entire global community by allowing countries to get ahead of the curve in detecting and preventing disease outbreaks before they even reach an airport. We commend St. Michael's Hospital for its innovation in using GIS to advance overall human health. We're proud to have provided the hospital with the technology to enable its vision."

As a winner, the Bio.Diaspora case study will become part of the Computerworld Honors International Program archive, which is available to researchers, students, and scholars via cwhonors.org and through digital records housed in national archives in over 350 universities, museums, and research institutions worldwide.

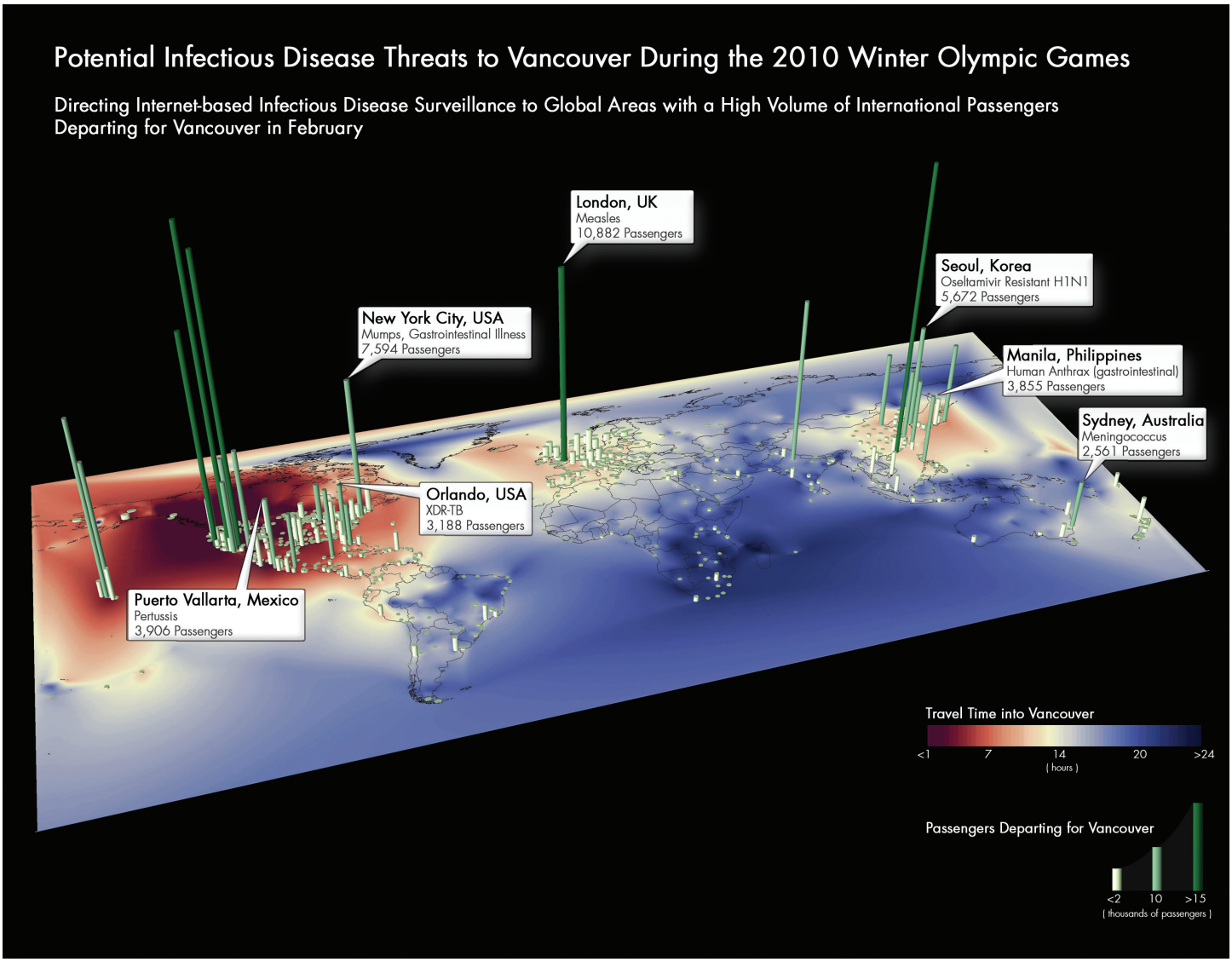
Khan said he was honored by the recognition but quickly noted that the hospital's goal—in collaboration with partners at Ryerson University and Harvard Medical School—has been to leverage GIS technology to offer real-time global situational awareness of infectious disease threats, strengthening public health security throughout the world.

"The Bio.Diaspora architecture enables us to quickly produce maps and put them on the web to seamlessly communicate our research findings," he explained. "We continue to move toward web mapping as a powerful vehicle to communicate our findings around the globe, helping to promote awareness, preparedness, and prevention of infectious disease threats."

Integrated Web-Based System

The Bio.Diaspora architecture consists of three key software components: SAS business analytics software, which integrates and manages data for tasks such as determining passenger flow volumes, identifying routes and transit points used most frequently by international passengers coming to Canada, and examining traffic trends over time; MATLAB technical

↓ The teams responsible for surveying people in Ethiopia for trachoma meet early in the morning before heading out to their assigned communities. Sixteen teams work to identify the disease in Ethiopia. (Credit: Dominic Nahr/Magnum/Sightsavers.)



computing software, which is used for data analysis and numeric computation; and ArcGIS software, which brings data to life through a range of compelling web maps.

For example, ArcGIS provides a way to create heat maps, contour maps, and simulations that could answer key questions such as, Where are the vulnerable points of entry in this province? What is the probability of the spread of infectious disease based on a defined set of criteria? How many international passengers arrived in a particular city in 2012?

Data sources are combined with data on worldwide passenger ticket sales, global flight schedules, and real-time flight status information. Bio.Diaspora facilitates an understanding of how people travel via commercial airlines and uses it as a way to predict how infectious diseases are most likely to spread around the world.

To enhance the application's capability to predict the spread of infectious disease at mass gatherings, the Bio.Diaspora team joined forces with the researchers at Harvard University who developed HealthMap, an online infectious disease surveillance system that uses ArcGIS for Server and monitors reports and warnings of outbreaks on the web at a local or regional level. An automated text-processing system evaluates more than 30,000 sources for disease outbreaks and their associated locations and maps the information on an interactive display.

The current Bio.Diaspora application has an integrated live stream of global epidemic intelligence from HealthMap and is capable of providing end users with valuable insights into where dangerous infectious disease threats are emerging in the world and where they are most likely to spread.

Together, Bio.Diaspora and HealthMap created a conceptual model that was applied to popular events including the 2010 Olympic Winter Games in Vancouver and the 2010 Fédération Internationale de Football Association (FIFA) World Cup.

For the 2010 Winter Olympics, the team members focused their infectious disease surveillance on the 25 cities where the majority of the travelers were predicted to originate. They also performed analyses to estimate the size of any potential surges in international air traffic that might coincide with the Winter Olympics. They accomplished this by analyzing historical trends in international air traffic over the past decade, including how global air traffic patterns changed during the previous Winter Olympics in Torino, Italy. Finally, they used data from flight schedules and network analysis to calculate the time required to travel from all commercial airports worldwide to Vancouver at the time of the opening ceremonies in February 2010. For pathogens with known incubation periods, information on travel times and travel routes to Vancouver could then have been used to assess the public health value of screening travelers upon arrival at Vancouver International Airport.

HealthMap was then leveraged to monitor disease outbreaks in the 25 cities of interest from which the majority of passengers traveled. The team took advantage of Really Simple Syndication (RSS) feeds to construct a dataset of news stories about infectious diseases that would be updated automatically. The analysis was performed on an hourly basis leading up to—and during—the Winter Olympics and identified three specific types of threats: infections with high capability of spreading from person to person through respiratory transmission or direct contact; infections that contained dangerous, drug-resistant pathogens; and threats that could be an act of bioterrorism.

"Real-time integration of web-based infectious disease surveillance, combined with knowledge of worldwide patterns of commercial air traffic, could significantly enhance global situational awareness of infectious disease threats," explained Khan.

This same conceptual model was applied to monitor infectious disease threats in South Africa for the FIFA World Cup. The team created a map that showed the high concentration of passengers traveling from 15 different cities, the time it would take those passengers to travel to South Africa, and the infectious disease threats that were present in those cities. For example, the map revealed that hand, foot, and mouth disease was present in Singapore; measles was present in Harare, Zimbabwe; mumps was present in London, England; and tuberculosis was present in Dakar, Senegal.

In the end, no major infectious disease threats were associated with either the 2010 Winter Olympics or the FIFA World Cup. However, if a serious threat had been identified, health officials from the host country would have known the country where the threat was first identified and therefore which health officials to contact. Health authorities and the public at the site of the gathering could have also been alerted to facilitate early detection of new cases.

Preventing Future Catastrophes

Information gleaned from the Bio.Diaspora and HealthMap conceptual model is now being used to interact with policy makers to improve global preparedness and response strategies. Khan and Brownstein currently have an advisory role with the World Health Organization (WHO).

In July 2012, when the Summer Olympic Games began in London, plans called for using Bio.Diaspora to assist public health officials in the United Kingdom by linking information on global infectious disease outbreaks with knowledge of patterns of travel to London. This integration would help health officials better understand what global outbreaks they needed to pay greatest attention to and subsequently anticipate and prepare for in case any threats were to spread to London. This collaboration represents the first time that such information will have been used in an operational manner to facilitate near real-time risk assessments of global infectious disease.

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