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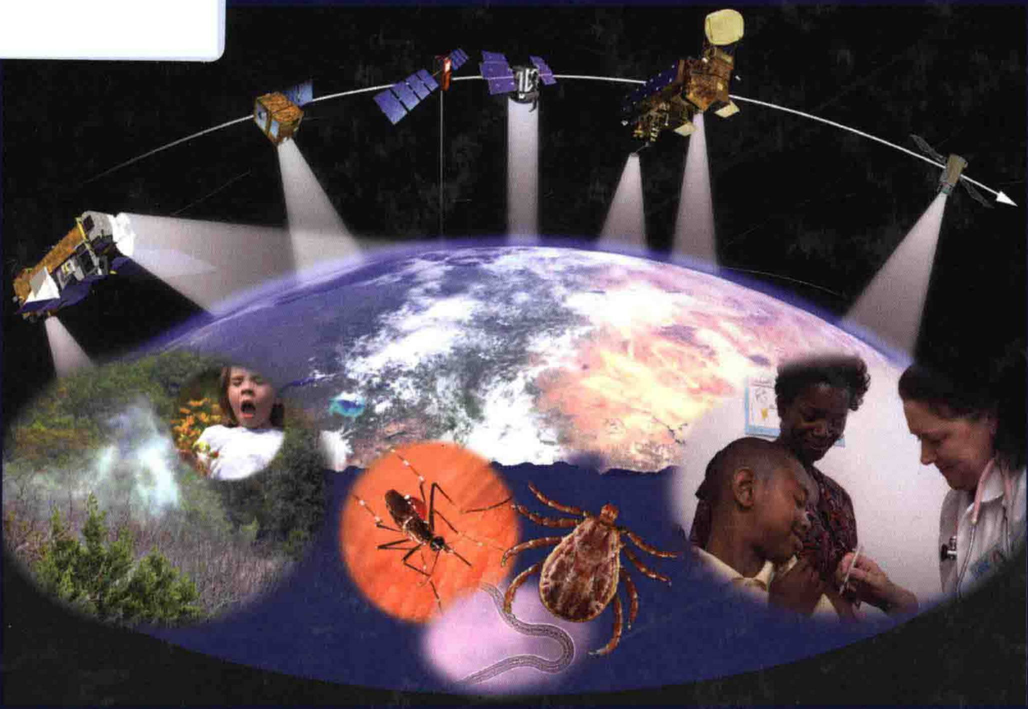

Environmental Tracking for Public Health Surveillance

Editors: Stanley A. Morain & Amelia M. Budge

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A BALKEMA BOOK

Environmental Tracking for Public Health Surveillance

Editors

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Cover image:
Environmental tracking involves a host of international space agency satellites and their on-board sensors. The upper portion of the image illustrates one of several satellite constellations (the *A-Train*) carrying land, ocean, and atmospheric sensors. The bottom three elements of the image show a pollen burst resulting in a respiratory reaction (left), typical disease carriers like mosquitoes, hookworms and ticks (center), and public health interventions like vaccinations (right). The challenge is to improve current environmental tracking capabilities with next generation sensor systems to predict disease threats and mitigate their outcomes.

Image credits:
A-Train: Courtesy US National Aeronautics and Space Administration (NASA)
Girl sneezing: Courtesy frogblog
Mosquito: Photo by James Gathany courtesy Centers for Disease Control and Prevention (CDC)
Tick: Photo by James Gathany courtesy CDC
Hook worm: Courtesy CDC
Boy being vaccinated: Photo by James Gathany courtesy CDC

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ENVIRONMENTAL TRACKING FOR PUBLIC HEALTH SURVEILLANCE

International Society for Photogrammetry and Remote Sensing (ISPRS) Book Series

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information from imagery

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Preface

The volume editors and Chapter author/editors have compiled a survey of health science research and application developments linking satellite Earth observations with types of diseases, their potential transmission pathways, and prospects for early warning of outbreaks or epidemics. Applying Earth science as a way to advance health science is both relevant and timely, given that in 2011 Earth's human population passed seven billion; and especially since health science includes broader social and economic factors that drive wellbeing and quality-of-life issues. The predominant focus is on global satellite observations that show how modelling space-based environmental measurements actually improve assessments of future health outcomes in scientifically valid ways. Its authors/editors and chapter contributors demonstrate that Earth's environments not only affect human exposures to disease but also serve as triggers for massive outbreaks and deadly epidemics.

The book was compiled by Chapter author/editors who addressed major categories of health and environment issues. Most lead author/editors invited additional international contributors to develop the Chapter content. The result is a collection representing the current state-of-the-art for environmental tracking for health surveillance, mitigation strategies, and policy decisions.

Some themes and topics recur in more than one Chapter. Information systems, for example are described in Chapters 6 and 10, but they describe different systems. In Chapter 6, *information systems* refer to data extraction from an extensive list of satellite sensors and their orbiting platforms, and the datasets and other products developed from them. In Chapter 10, *information systems* refer to tracking environmental parameters and suites of parameters for assessing transmission pathways and for health monitoring and forecasting. The Chapter also addresses semantic approaches to *information systems* as tools for identifying health threats rapidly based on global networks of media sources, the potential for crowd sourcing, and other forms of social networking for identifying evolving health threats that could slide from order to chaos in a matter of hours.

The reference section at the end of each Chapter is a compendium of citations for readers to extract the history and development of thought surrounding air-, water-, vector-, and soil-borne diseases and zoonotic diseases. By and large the author/editors and their contributors have strengthened convergence of the two scientific philosophies. We are confident that this volume will become a stimulus for greater cooperation among the sciences, and become a source reference for several years to come.

The following two conventions have been adopted to provide consistency between Chapters. First, while recognizing that Universal Record Locators (URLs) can be ephemeral, they nevertheless point to important resources for online data and information. The speed of communication is such that on-line publishing results in URLs as the best means for retrieving information. Evolving search engines will no doubt lead inquirers to a wealth of additional resources. Chapters that cite many URLs include tables in their text to relevant Sections or sub-Sections that point to them. Additional URLs are cited in the reference sections.

The second convention recognizes that readers will be interested in specific sensors, sensor systems, services, diseases, or medical and health terms that recur frequently in Chapters. All scientific terms are spelled out at the place of their first use in the book; and thereafter, by acronym only. Acronyms for proper titles (satellite platforms, satellite missions and experiments, international organizations, programmes, commissions, and centres) are capitalized at their first use in the text and thereafter by acronym only; those referring to orbiting sensors, government or university systems, online systems, services, models, or processes are *not* capitalized at their first use in the text, but are given as acronyms in subsequent references; and those acronyms used only locally by authors pertinent to their material, but not otherwise recognized widely as acronyms, are not included in the list of acronyms. Readers interested mainly in material in the later Chapters will find acronyms spelled-out in earlier Chapters, and will need to refer to the comprehensive list of acronyms provided at the end of the book. Lastly, the United Kingdom and the United States are given as UK and US. All other countries are spelled out.

This work is a product of the International Society for Photogrammetry and Remote Sensing (ISPRS): Commission VIII – *Remote Sensing Applications and Policy*/ Working Group-2 – *Health*. The working group had an international membership of over fifty active and passive remote sensing and health science experts during its four-year commission from July 2008 to September 2012.

Albuquerque April 30, 2012
Amelia Budge, Chair
Richard Kiang, Co-Chair
Stan Morain, Technical Secretary

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Foreword

Justinian's Flea (Rosen 2007) explores a systems approach to understanding the decline of the Roman Empire, a centuries-long process involving political, religious, economic, social, military, and personality threads interacting over a gradually changing physical environment. The arrival of the plague bacterium (*Yersinia pestis*) to the lower Nile valley around 542 AD, and its subsequent spread throughout the Mediterranean region, reshaped the political and social orders of Europe, and in no small way represented the final straw that destroyed the Empire. In the context of Environmental Tracking for Public Health Surveillance, *Y. pestis*, the flea that hosted it, and the black rat that transported it, became possible through a minor lowering of temperatures that *brought the coast within the [bacterium's] active temperature range of 59–68 degrees Fahrenheit* (Brown 1999). According to tree ring analyses and historical evidence, such a cooling took place around 530 AD. *Y. pestis* migrated from its East African focus where it had been active for hundreds, if not thousands of years, and along the way apparently jumped to human populations. Justinian nor anyone else in the mid-sixth century could have foretold the horrifying health consequences of a slightly cooler temperature along the southern Mediterranean coast.

Estimating the moment when climate, flea behaviour, food availability [wheat for the rats], and a dozen other variables [would] combine to cause a rat population explosion is not impossible, but very nearly so (Rosen 2007, 291). These words are a reminder that complexity is, at best, able to balance *order* and *chaos* only temporarily. While physics and math provide precise solutions to two-body problems whose parameters are measurable, they provide only vague approximations to problems governed by multiple interacting influences whose parameters are not known as well, and whose impacts on system function are nonlinear.

Twenty-first century environmental health tracking, made possible by vastly superior science and technology capabilities (compared to the early centuries AD), suggest that we *can* foretell health scenarios, and do so at almost any geographic or human scale we choose. Why, then, do we not? According to Sterman (2006) it is because we do not convince policy and decision makers. He argues in favor of scientific methods and formal modelling to guide policy decisions for otherwise intractable system dynamics, all the while knowing that the greater the number of interacting components, the more complex the system will become. Complexity hinders the generation of evidence, learning from that evidence, and implementing policies based on that evidence. *System thinking requires us to examine issues from multiple perspectives, to expand the boundaries of our mental models, [and] to consider the longer-term consequences of our actions, including their environmental, cultural, and moral implications* (Sterman 2006, 511).

It is safe to argue that early civilizations made little, if any, connection between diseases and their possible underlying causes either at an individual or societal level. The empires of Greece, Rome, Macedonia, China, Peru, Mexico and elsewhere could not connect cause and effect (aetiological) relationships. Yet, at the everyday level, early populations had fundamental beliefs that the common cold was somehow rooted in cold weather; that some plants were poisonous; that fevers were brought on by something in the victim's daily experiences; or that there were supernatural forces at work.

Not being a history of health and medicine, this book fast-forwards to the last quarter of the 20th Century and the advent of satellite observations of Earth. These digital data and the products derived from them not only provide the means for monitoring ever-changing environmental parameters, but also contain clues to identify conditions that trigger health consequences. The Chapters focus on a variety of observations that are known to affect health. Some of these reveal slowly changing or emerging environments; others represent dramatic events having quick and often catastrophic health consequences.

On the cusp of the 21st Century it became apparent to world bodies that environment and health were tightly linked. The first principle to emerge from the 1992 United Nations Conference on Environment and Development held in Rio de Janeiro was that *Human beings are at the center of concerns for sustainable development. They are entitled to a healthy and productive life in harmony with nature.* Here, perhaps, is an early convergence of environmental health with public health. Ten years later at the 2002 World Summit on Sustainable Development (WSSD), the Johannesburg Plan of Implementation (POI) was adopted (UN 2004). In this Plan, paragraphs 53–57 refer specifically to human health issues. It is stated that *there is an urgent need to address the causes of ill health, including environmental causes, and their impact on development, and to reduce environmental health threats* (UN 2004, 31).

Many challenges in Earth system science require not only integrating complex physical processes into system models, but also coupling environmental biogeochemical and chemical phenomena that trigger human health responses. The next generation of modelers will be required to form teams that partner members from the biogeophysical realm with those from the medical realm to assess quickly changing and highly vulnerable situations.

People and Pixels (Liverman *et al.,* 1998) was among the early publications to draw humankind into the arena of satellite remote sensing. Early scientific literature focused on physical and natural applications in agriculture, forestry, rangeland, hydrology, and mineral exploration. After *People and Pixels*, interest migrated to people-oriented issues like food security, environmental health, public health, disasters and hazards, and most recently on security and antiterrorism. Because of their immense humanitarian and policy implications, remote sensing and geospatial programmes are moving quickly to address the consequences of weather and climate cycles on human health, air and water quality degradation, and diseases following natural disasters. For the photogrammetry, remote sensing, and geospatial information sciences, the key language in Paragraphs 54 and 56 in the POI includes the following. For the most part they are general aims and goals, but a few are quite specific.

§54: Integrate health concerns into strategies, policies, and programs for sustainable development; provide technical and financial assistance for health information systems and integrated databases; target research efforts and apply research results to priority public health issues and reduce exposures to public health risks; start international initiatives that assess health and environment linkages; and, develop preventive, promotive, and curative programs for non-communicable diseases.

§56: Reduce respiratory diseases and other health impacts resulting from air pollution.

Once articulated, it was inevitable that genetic and molecular systems would eventually be linked with the broader biogeochemical forces of nature.

Stan Morain, May 9, 2012

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Acronyms

ACE	Atmospheric Chemistry Experiment
ACES	Applied Climate for Environment & Society
ADAM	Asian Dust Aerosol Models
ADDS	Africa Data Dissemination Service
ADHS	Arizona Department of Health Services
AFO	Animal Feeding Operations
AFRIMS	Armed Forces Research Institute of Medical Sciences
AI	Avian Influenza
AIC	Akaike Information Criterion
AIDS	Acquired Immune Deficiency Syndrome
AIRS	Atmospheric Infrared Sounder
Aka	Also Known As
ALADIN	Aire Limitee Adaptation Dynamique INitialisation
ALI	Advanced Land Imager
AMSR-E	Advanced Microwave Scanning Radiometer-EOS
AOD	Aerosol Optical Depth *aka* Aerosol Optical Thickness
API	Annual Parasite Indices
APRHB	Air Pollution and Respiratory Health Branch
AQS	Air Quality System
ARC	Ames Research Center
ARIMA	Autoregressive Integrated Moving Average
AROME	Applications of Research to Operations at Mesoscale
ASDC	Atmospheric Science Data Center
ASP	Amnesic Shellfish Poisoning
ASTER	Advanced Spaceborne Thermal Emission & Reflection Radiometer
ATSDR	Agency for Toxic Substances & Disease Registry
AVHRR	Advanced Very High Resolution Radiometer
AVIRIS	Airborne Visible/Infrared Imaging Spectrometer
BEBOV	Bundibugyo Ebola Vrus
BFU	Bacterial-colony Forming Unit
BI	Business Intelligence
BIDSS	Border Infectious Disease Surveillance System
BRT	Boosted Regression Trees
BSA	Black-Sky Albedo
BTD	Brightness Temperature Difference
CABLE	CSIRO Atmosphere Biosphere Land Exchange
CAFO	Concentrated Animal Feeding Operations
CALIOP	Cloud & Aerosol LiDAR Orthogonal Polarization
CART	Classification & Regression Tree
CAS	Complex Adaptive System
CASTNET	Clean Air Status & Trends Network
CATHALAC	Water Center for the Humid Tropics of Latin America & the Caribbean
CBEPS	Chesapeake Bay Ecological Prediction System
CCAD	Central American Commission for Environment & Development