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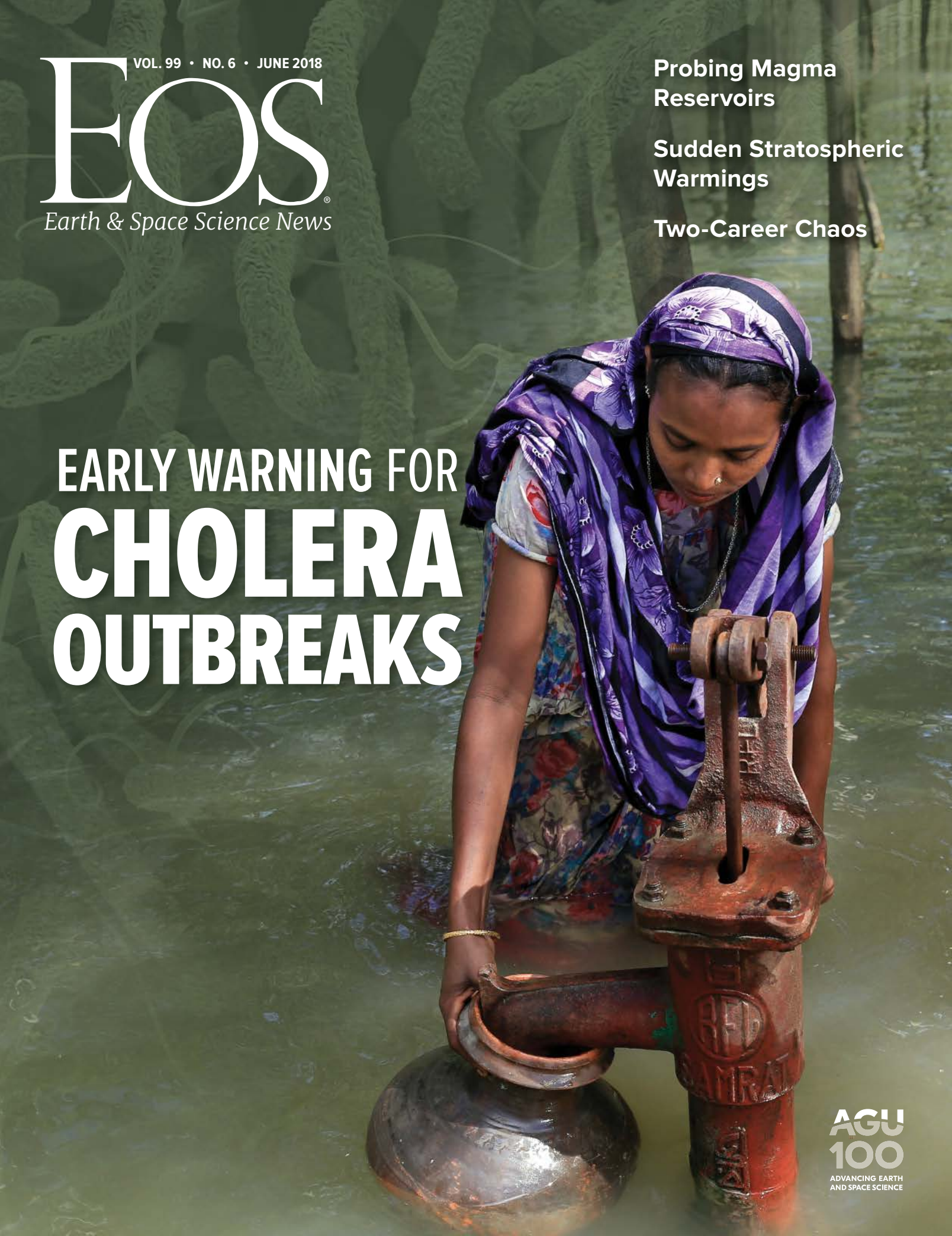

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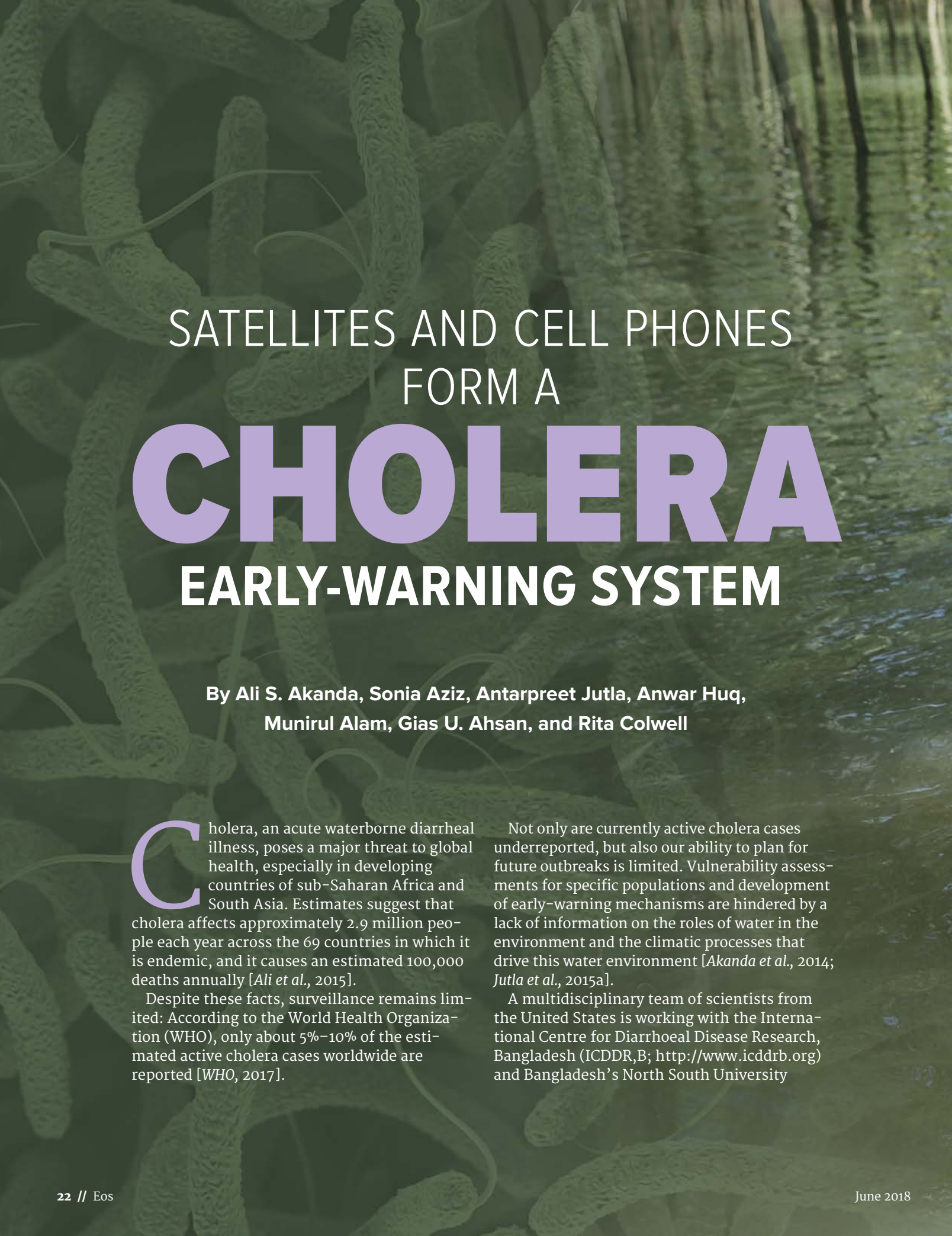

SATELLITES AND CELL PHONES FORM A CHOLERA EARLY-WARNING SYSTEM

By Ali S. Akanda, Sonia Aziz, Antarpreet Jutla, Anwar Huq, Munirul Alam, Gias U. Ahsan, and Rita Colwell

Cholera, an acute waterborne diarrheal illness, poses a major threat to global health, especially in developing countries of sub-Saharan Africa and South Asia. Estimates suggest that cholera affects approximately 2.9 million people each year across the 69 countries in which it is endemic, and it causes an estimated 100,000 deaths annually [*Ali et al.*, 2015].

Despite these facts, surveillance remains limited: According to the World Health Organization (WHO), only about 5%–10% of the estimated active cholera cases worldwide are reported [*WHO*, 2017].

Not only are currently active cholera cases underreported, but also our ability to plan for future outbreaks is limited. Vulnerability assessments for specific populations and development of early-warning mechanisms are hindered by a lack of information on the roles of water in the environment and the climatic processes that drive this water environment [*Akanda et al.*, 2014; *Jutla et al.*, 2015a].

A multidisciplinary team of scientists from the United States is working with the International Centre for Diarrhoeal Disease Research, Bangladesh (ICDDR,B; http://www.icddrb.org) and Bangladesh's North South University

A Bangladeshi village woman collects water from a tube well, which taps a shallow unconfined aquifer, amid surroundings flooded with contaminated water. Credit: Mushfiqul Alam/NurPhoto/Getty Images

(http://www.northsouth.edu) to address these critical problems of prediction, preparation, and prevention. The team's new initiative combines satellite remote sensing data with ground observations to assess and predict the risk of cholera outbreaks in vulnerable populations of the country.

A Cyclical Problem

In Bangladesh, waterborne diarrheal diseases are the most prevalent illnesses and have a significant impact on public health and the national economy [*Daily Star,* 2017]. The country suffers from a chronic scarcity of safe water and sanitation access. The monsoonal climate causes drastic environmental changes from season to season. Water sources are highly susceptible to pathogen contamination, including widespread cholera bacteria native to the aquatic environment [*Akanda et al.,* 2013].

In the absence of data, experts have used estimates based on past surveillance and demography to suggest that the effects of large-scale processes (e.g., droughts, floods, coastal storms) put approximately 66 million people in Bangladesh at risk of cholera infection. Approximately 300,000 cases occur there each year, causing an estimated 4,500 deaths [*Qadri et al.,* 2015]. Rapid urbanization has worsened these trends; waterborne diarrheal disease outbreaks occur in informal settlements and villages across the country during both the dry season and monsoon floods [*Akanda and Hossain,* 2012].

Studies have linked this disease burden to two seasonal transmission cycles driven by regional coastal and terrestrial geophysical processes [*Akanda et al.,* 2013; *Jutla et al.,* 2015b]. Severe water scarcity during the prolonged dry season (November through April) affects water quality in inland freshwater bodies and causes salt water to intrude into coastal areas. Such intrusion brings cholera bacteria, which thrive in this salt water, and exposes a vast population to the risk of infection in southern Bangladesh.

The situation reverses when the monsoon season arrives in June; more than 80% of Bangladesh's annual rainfall occurs in just four months (June through September). The heavy rains destroy safe water sources and sanitation infrastructure, and the flood-induced contamination moves across water networks. Receding floodwaters, rich in nutrients and pathogens, lead to a second wave of outbreaks in postmonsoon months.

Analysis shows that a majority of the vulnerable population is willing to change its preferred water collection methods or sanitation and hygiene habits during these high-risk periods if given advance warning. However, limited information and resource constraints often preclude taking protective action [*Aziz et al.,* 2015].

Forecasting a Cholera Outbreak from Space

To develop forecasts of the risk of a cholera outbreak across Bangladesh, the team monitors regional hydroclimatic processes and changes in the natural aquatic ecosystem with near-real-time Earth observations (EO) obtained from a constellation of NASA satellites (Figure 1). It incorporates precipitation data from the Tropical Rainfall Measuring Mission satellite and its successor, the Global Precipitation Measurement mission (TRMM-GPM); air temperatures from the Moderate Resolution Imaging Spectroradiometer (MODIS) instrument; and water storage information from the Gravity Recovery and Climate Experiment (GRACE) satellites.

These data, along with data from other sensors and hospital and socioeconomic data, are used to assess the hydroclimatological risk of cholera in the study region [*Jutla et al.,* 2015b]. Project findings and results are being used to map unsafe water sources, prepare warnings related to water quality, and predict the potential of natural disasters.

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The project findings assist in filling critical information gaps on what, when, and where levels of risks exist and which preventive measures should be taken to deal with problems of unsafe water and sanitation access during critical seasons of the year. To determine the breadth of issues in the environment, the team is implementing a pilot project in two remote locations inside Bangladesh—one coastal and one inland—that represent contrasting underlying processes. The ongoing project generates awareness among vulnerable populations and local public health departments.

Willing Residents Need Information

The team conducted surveys on water usage and practices among at-risk households in the coastal Mathbaria area, in the rainfall-heavy inland Chhatak region, and around urban slums in Dhaka. It also interviewed institutional stakeholders (government offices, hospitals, nongovernmental organizations, and others) regarding their understanding of cholera outbreaks, related geophysical processes, and potential uses of an early-warning system.

Interviews with residents and local administration officials in the Mathbaria area revealed that during the dry spring season, a lack of freshwater from upstream rivers and subsequent saltwater intrusion into estuarine areas render most local water sources unsafe to drink. These events also cause contamination with cholera bacteria, which thrive in brackish water.

The surveys found that flooding periodically destroys water infrastructure (e.g., levees and dams) in the Chhatak region. Flooding persists for prolonged periods, even after

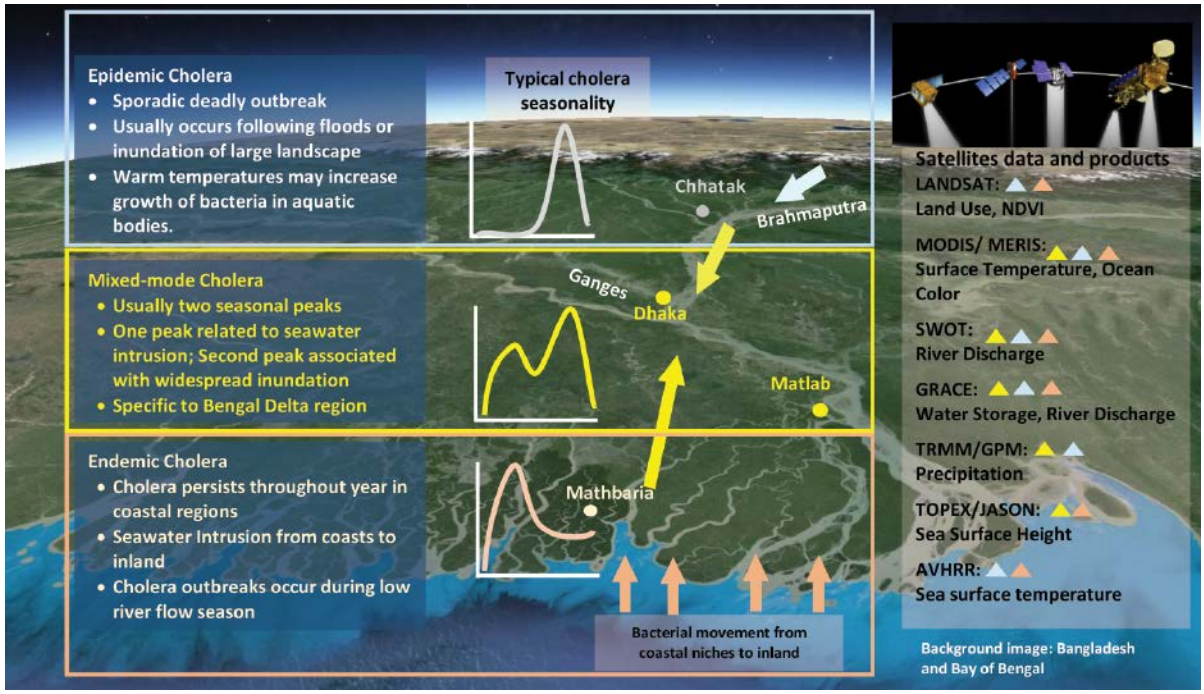

Fig. 1. A constellation of NASA satellites provides Earth observation data for assimilation into a cholera early-warning framework for Bangladesh. Triangles correspond to the type of cholera monitored using each satellite's data. Abbreviations are NDVI, Normalized Difference Vegetation Index; MODIS, Moderate Resolution Imaging Spectroradiometer; MERIS, Medium Resolution Imaging Spectrometer; SWOT, Surface Water and Ocean Topography; GRACE, Gravity Recovery and Climate Experiment; TRMM, Tropical Rainfall Measuring Mission; GPM, Global Precipitation Measurement; TOPEX, Ocean Topography Experiment; JASON, Joint Altimetry Satellite Oceanography Network; and AVHRR, Advanced Very-High-Resolution Radiometer.

a monsoon passes, providing a rich source of nutrients for cholera bacteria and putting a large population at risk of infection. Residents recognized that these outbreaks recur seasonally, but they exhibited a general lack of awareness about the health dangers of unsafe water and the effect of natural disasters on water safety.

Of the families interviewed, 94% indicated that they are willing to change their water procurement and hygiene habits during times of high cholera risk if given advance warning. Water procurers, usually female heads of households, are critical to ensuring that these changes are implemented.

Furthermore, 81% of the sampled population is willing to reveal personal cell phone numbers to receive early-warning messages via an app or text message; this demonstrates a high potential for effective information dissemination. The team found that social media websites, such as Facebook, have very high penetration in rural Bangladesh and urban slums in Dhaka. More than 85% of the people surveyed in urban slums use a smartphone that offers ready access to social media. Special subscription packages from most local cell phone service providers enhance this access still further.

Getting the Word Out

Under the auspices of our project, predictions of high cholera risk periods will be disseminated to agencies responsible for public health, to the overall decision-making hierarchy, and to residents of the vulnerable areas. The project's partner nongovernmental organizations will advise local water and sanitation regulators and practitioners during periods of heightened risk of cholera. The team will disseminate updates of seasonal and spatial variability of risks and conditions on the ground directly to stakeholder organizations by distributing flyers in the local language (Bengali), conducting awareness workshops, and issuing warnings via cell phones and social media.

The team expects these forecasts to improve the ways in which people in vulnerable locations seek water and their sanitation practices during the critical seasons of the year. As the global health community transitions from Millennium Development Goals to Sustainable Development Goals (see http://bit.ly/UN-millennium and http://bit.ly/UN-sustainable), similar EO-guided initiatives can play a critical role in meeting water, sanitation, and public health–related development objectives.

Acknowledgments

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Village women collect water from polluted ponds in coastal Bangladesh. During the dry spring season, salt water flows back from the ocean into coastal estuaries, bringing cholera bacteria with it. Credit: Antarpreet Jutla

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Author Information

Ali S. Akanda (email: akanda@uri.edu), University of Rhode Island, Kingston; **Sonia Aziz,** Moravian College, Bethlehem, Pa.; **Antarpreet Jutla,** West Virginia University, Morgantown; **Anwar Huq,** University of Maryland, College Park; **Munirul Alam,** International Centre for Diarrhoeal Disease Research, Bangladesh, Dhaka; **Gias U. Ahsan,** School of Health & Life Sciences, North South University, Dhaka, Bangladesh; and **Rita Colwell,** Center for Bioinformatics and Computational Biology, Institute for Advanced Computer Studies, University of Maryland, College Park