Spying Diseases from the Sky

Satellite data may predict where infectious microbes will strike

By JOHN TRAVIS

The myriad satellites that whip around the globe enable people far below to study the stars, spy on one another, forecast weather, make phone calls from a car, and watch television channels crammed with sitcoms, soaps, and sports. To a small group of scientists, orbiting spacecraft suggest another intriguing use: predicting when or where debilitating and deadly infectious diseases are likely to strike.

This seemingly fanciful notion is rooted in the idea that disease-causing microbes, or the infected insects and other creatures that transmit these microorganisms to people or animals, normally reside in identifiable environments. Landscape epidemiology, as the theory is known, holds that researchers can therefore use features of the landscape to identify specific areas where the risk of transmitting these diseases is greatest.

Some researchers following this approach are now taking an eagle's eye view of their target with aircraft and satellites that snap high-resolution pictures, record wavelengths of reflected light, measure ocean temperature, and capture other data useful in classifying the landscape.

"You have this satellite in space and these little microbes on the ground and you can relate the two. That's pretty amazing," says Durland Fish of Yale University School of Medicine, who has used remote sensing to help predict Lyme disease risk in areas of New York State.

The National Aeronautics and Space Administration has for more than a decade encouraged the marriage between remote sensing technology and infectious disease research. From 1985 to 1995, for example, NASA used satellite images of rice fields in California and villages in Mexico to identify the landscape features favorable to malaria-causing mosquitoes.

In Mexico, the investigators found that nearby wetlands and unmanaged pastures tended to ensure an abundance of mosquitoes. In one test, a model based on such landscape features identified 79 percent of mosquito-plagued villages in Mexico.

Several years ago, NASA formed the Center for Health Applications of Aerospace Related Technologies (CHAART) at the Ames Research Center in Mountain View, Calif.

One recent CHAART project addressed Lyme disease, a growing concern in the United States. The illness results when ticks, usually carried by deer, feed on small mammals infected with *Borrelia burgdorferi* and then transmit the bacterium to people they bite.

While there have been extensive efforts to educate people about avoiding tick-infested areas, Fish argues that it would be more cost-effective to direct information to those most at risk. Over the last few years, he and his colleagues have attempted to determine whether satellite imagery can reveal specific regions whose residents should be targeted.

In an initial study, they analyzed vegetation patterns in New York's Westchester County in conjunction with the extensive records of dogs that carry antibodies to *B. burgdorferi*. The study found that residences bordering wooded areas and containing shade trees and ornamental plants posed the greatest danger of infection. Woods are the natural habitat of infected deer, and when the animals slip into yards to feed on ornamental plants, they can leave a trail of ticks. The ticks thrive in the moist ground of shaded areas, explains Fish.

In more recent work, the researchers determined the abundance of ticks on 350 properties in the county. With the help of CHAART, the investigators correlated those data with landscape features provided by satellite imagery and developed a predictive model of Lyme disease risk for the county. Their results have been accepted for publication in the AMERICAN JOURNAL OF TROPICAL MEDICINE AND HYGIENE.

"Give me the name of anyone in Westchester County, and I can look it up in a digitized phone book, I can get out the digitized maps and find out exactly where he lives, I can overlay the satellite imagery, look at the greenness and wetness values, plug them into charts and formulas and say 'high risk' or 'low risk' with 77 percent accuracy," says Fish.

Companies developing Lyme disease vaccines have already expressed an interest in such models, he adds.

Even harmful bacteria that dwell in the oceans may not escape the scrutiny of satellites. At an American Society for Microbiology meeting in Miami Beach this May, Rita R. Colwell of the University of Maryland Biotechnology Institute in College Park discussed remote sensing efforts to spy on cholera.

A potentially devastating disease, cholera results when the bacterium *Vibrio cholera* infects the gut and releases a toxin. Infected people develop severe diarrhea, shedding gallons of water within a day. The resulting dehydration triggers fever, shock, organ failure, and usually death. Replacing the lost fluid and electrolytes can stem this progression.

While cholera maintains a constant presence in India, Bangladesh, and nearby countries, the disease has mysteriously swept the world seven times since 1817. The most recent pandemic, involving a strain of *V. cholera* slightly less deadly than most, began in 1961 and continues today.

Since 1855, investigators have known that cholera outbreaks typically erupt in areas where people drink unsanitized water.

In the last decade or so, Colwell and her colleagues have found that *V. cholera* naturally attaches to copepods and other microscopic ocean animals that feed on phytoplankton, the microscopic plants that Colwell calls the "grass of the sea." Warm water can stimulate phytoplankton blooms, which then cause an increase in copepod populations and presumably *V. cholera*. Researchers have suggested that climate changes which warm the oceans may help explain the timing of some cholera outbreaks (SN: 4/6/96, p. 218). In 1991, for example, cholera struck South America for the first time in a century, an event that coincided with a warming of Pacific waters.

Working with CHAART, Colwell's group has sought to correlate satellite data on coastal waters with the annual fall and spring outbreaks of cholera in Bangladesh. Using data from 1992 to 1995, the scientists discovered that the number of cholera cases in Bangladesh usually paralleled, with delays of a week or more, the rise and fall of water temperature in the Bay of Bengal.

The one exception was 1993. In that year, the region had an abnormally small number of cholera cases. The height of the ocean was also unusually low, according to the satellites. Ocean height determines how far upstream the *V. cholera*–infected waters penetrate the rivers that feed the Bay of Bengal.

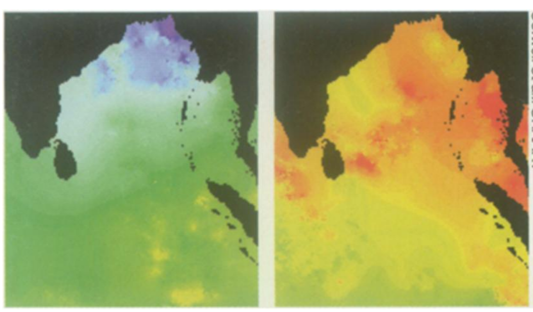
"It was clear that ocean height might explain why there were so few cases that year," says CHAART's Brad Lobitz.

The researchers are still trying to correlate other ocean attributes, such as turbidity, with cholera cases. They're also looking forward to spotting phytoplankton blooms. A U.S. craft scheduled for launch this year should provide the ocean color data needed to estimate chlorophyll content, an excellent indicator of phytoplankton abundance, says Lobitz.

Ultimately, says Colwell, remote sensing may help researchers provide early warnings of when and where cholera will strike. Such warnings may encourage people to take extra precautions with their drinking water.

Another CHAART-aided project concerns visceral leishmaniasis, a tropical illness now wreaking havoc in major Brazilian cities and in countries such as India and Sudan. The disease, fatal if untreated, stems from parasitic protozoans transmitted to people through the bite of infected sand flies.

"In the last decade or so, it's moved into urban centers in epidemic form. The potential for disaster is great," says James Maguire of the Harvard School of Public Health in Boston.

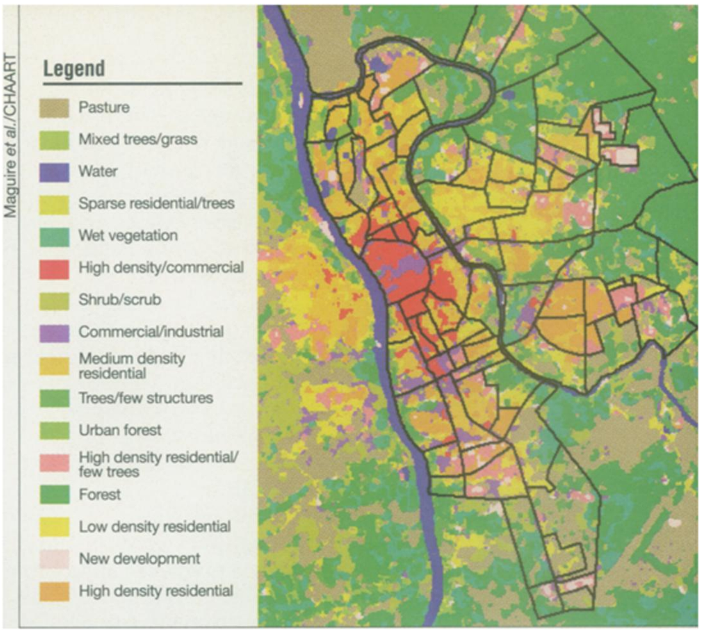


Colwell et al./CHAART

Sea surface temperatures (lowest to highest: purple-blue-cyan-green-yellow-orange-red) in the Bay of Bengal in January (left) and April (right) 1992.

Visceral leishmaniasis is usually curable if caught early, but treatment involves a month or two of daily injections, an expensive regimen for people in developing countries and one that sometimes causes significant side effects. Consequently, public health officials are desperate to prevent rather than have to treat infections, says Maguire.

Researchers know that sand flies prefer to dwell in dark, shady places, but it's unclear exactly what urban environments place people at greatest risk of visceral leishmaniasis. By comparing a Landsat image of Teresina, Brazil, to the citywide distribution both of dogs infected with the parasite and of people with the disease, investigators have begun to examine whether certain types of vegetation, amounts of soil moisture, and locations of residences favor infections. "One can start to narrow down parts of the cities that need attention," says Maguire.



Maguire et al./CHAART

This map of the 74 districts in Teresina, Brazil, stems from an analysis of a Landsat image taken in 1995.

At this early stage of analysis, conclusions are general. Districts with extensive forested land and low- to medium-density housing seem to record the highest rates of human disease and canine infection, says Maguire.

The satellite imagery has already provided a new direction for research into how the disease is transmitted. Public health officials generally consider infected dogs the main reservoir of the parasites causing visceral leishmaniasis, yet Brazil has spent lots of money and effort killing infected dogs without having much impact on the spread of the disease, notes Maguire.

When he and his colleagues analyzed the satellite imagery and spatial distribution of the disease, they noticed that cases were often concentrated in regions of the city linked to forest areas by a "green corridor" of vegetation.

Instead of dogs, perhaps foxes entering the city through such corridors are the crucial reservoir for the parasites, speculates Maguire. The researchers plan to capture foxes near Brazilian cities to see whether the animals harbor the parasites. This study "wouldn't have happened without the satellite images," says Maguire.

Not all remote sensing efforts require satellites. Take recent U.S. attempts to spot illegally dumped scrap tires.

Such tires offer fertile breeding grounds for several mosquito species that can carry human and animal diseases such as yellow fever and encephalitis. As states have enacted new laws and taxes concerning tire disposal, illicit dumping of scrap tires has increased.

Most unlawful tire dumps are discovered only by accident. Recently, Fred W. Knapp and Mark Beavers of the University of Kentucky in Lexington found that a low-flying aircraft equipped with imaging equipment can spot dumped tires via the characteristic wavelengths of light that the tires reflect.

The technique is so effective that, when the leaves are off the trees, it can detect piles of as few as 10 tires, say the researchers. "Now it's up to the states [to use this technology]," says Knapp.

While the researchers believe in the benefits of remote sensing, public health agencies, overwhelmed by the effort to fulfill their many mandates with dwindling budgets, haven't rushed to adopt the high-tech approaches. "They don't want any new problems or more work to do. Eventually, they'll realize it's useful information," contends Fish.

"It's a slow process," agrees CHAART's Byron Wood, "but interest has grown dramatically over the last few years."

In the meantime, NASA continues to encourage infectious disease scientists to explore the possibilities of remote sensing. This year, CHAART will train 10 researchers from developing countries in remote sensing techniques that they can then apply to their homelands' problems.

Wood and the other researchers with experience using the technology to tackle infectious disease acknowledge that their interdisciplinary endeavor is an immature field striving to prove itself. "The real question is whether this [technology] will be useful or not. The honest answer is that we're trying to find that out . . . and hoping that it will be," concludes Maguire. □