That obstacle also has hindered efforts to add an extra terminal, or gate, to the diamond cathodes—a drain as well as a cathode and anode—that allows for more precise control of the flow of electrons. At the meeting, however, two research groups have reported success in fabricating three-terminal, or gated, diamond arrays. In a display, for example, a gated array would mean faster, more precise switching on and off of pixels.

One team, at Vanderbilt University in Nashville, Tennessee, started with a pyramidal mold for the deposition of diamond film. They added terminals and backing, using conventional semiconductor fabrication techniques. Finally, the mold material was etched away. The result was a uniform pattern of diamond pyramids in a three-terminal configuration. Electrical engineer Jim Davidson says the array "could significantly outperform silicon devices in speed, power [consumption], and reliability" once some practical problems are solved. Among these is a tendency to get reverse current flow between the gate and the tip, which limits the three-terminal performance.

Wolfgang Mueller of Research 2000 Inc., a start-up company in Westlake, Ohio, described tests on an approach that dodges the problem of fashioning an array of diamond points. Starting with a silicon substrate, he adds a grid of an insulating material topped by a second conductive layer laid down in wide lines. The wells between the grid lines then get a sprinkling of diamond crystals. Passing a current from the substrate through the diamond crystals to the top conductive layer induces field emission in the diamond that should send streams of electrons to an anode above the semiconductor sandwich. This would be an extremely simple and easy way to fabricate a three-terminal array. However, Mueller and his team have yet to add the anode and make precise measurements of emission currents. "It is very recent work," he explains.

While researchers are still struggling with diamond emitters, a group led by Yahachi Saito, an associate professor of electrical and electronic engineering at Japan's Mie University, is staking its efforts on carbon nanotubes as field emitters. The team mounted a wafer of multiwalled carbon nanotubes on a substrate and treated the surface with an etch to remove carbon debris and expose the tips of the nanotubes. Then, they put this cathode in a thumb-sized vacuum tube with an aluminum film anode and a phosphor screen. This CRT lighting element emits a bright light that remains stable for 10,000 hours, promising to bring the brightness and resolution of the CRT to flat-panel displays. Ise Electronics Corp., which is collaborating on the work, has already adapted the device for use in a rudimentary flat-panel display.

But Saito says there are still formidable challenges to commercializing the technology. Scaling up the production of the device is one hurdle, as is making large quantities of the nanotubes themselves, now created by passing an arc discharge between graphite electrodes in a helium environment. "We've succeeded with an experimental device, but it's not clear yet if we can successfully commercialize it," Saito says.

A team at Delft University of Technology and Philips Research Laboratories in the Netherlands is studying carbon nanotubes as a possible electron source for electron microscopes. The big advantage of carbon nanotubes in that environment would be their ability to emit electrons in an extremely narrow energy range. "The more monochromatic the source is, the better electron lenses can be used to focus the beam," says physicist Martijn Fransen. A single, multiwalled carbon nanotube produced an energy spread of just 0.11 electron volts, compared with a spread of 0.6 to 0.3 eV from the best electron sources currently being used. "The difference doesn't seem like much, but it's quite important to get [the value] lower," he says. The biggest challenge, according to Fransen, is reducing the variability in emission characteristics among nanotube samples.

Indeed, field-emission researchers are now thinking far beyond flat-panel displays, which inspired the early work on the technology. Other groups reported attempts to use them in image sensors, mass spectrometers, and even in a surge absorber for high-speed computer communication lines, in which the surge of energy is diverted to emit electrons. But much more work is needed before emitters can deliver on their promises. "The easy experiments have been done," says Ian Milson, a researcher at EEV Limited, a British company considering ways to commercialize field-emission technologies. "The problems left are the difficult ones."

–DENNIS NORMILE

ECOLOGY

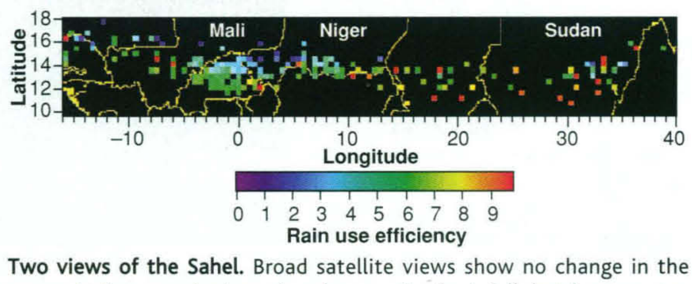
The Sahara Is Not Marching Southward

From a satellite perch, the supposed steady encroachment of desert into Africa's Sahel appears instead to stem from climate variation

Twenty-five years ago, the Sahel—the narrow band of barely habitable semiarid land stretching across Africa at the southern edge of the Sahara—was thought to be on the verge of disappearing. Images beamed around the world showed deep drought, starving millions, and land stripped of vegetation by man and beast as human activity turned the land into permanent desert. Sub-Saharan Africa became the embodiment of "desertification," the human-driven, irreversible expansion of the world's deserts. Thought to be gobbling up tens or even hundreds of thousands of square kilometers of arable land every year, desertification provoked an outpouring of aid and an international treaty.

For the past decade, however, scientists armed with ecological studies have been fighting the idea that such desertification is wide-spread or largely human induced. Now, they have satellite images to bolster their argument that much of what has been called desertification was instead the reflection of natural ups and downs of rainfall.

"We're not trying to say desertification is not happening," says climatologist Sharon Nicholson of Florida State University in Tallahassee, lead author of one of two recently published satellite studies. "We're saying the scenario of the Sahara sands marching southward at the hands of humans is wrong." The studies show that natural climate variation has shifted the desert's edge, with no net effect on the amount of vegetation. Although people may be degrading the drylands of the Sahel, mainly by changing the mix of plants, they aren't expanding the desert.



Two views of the Sahel. Broad satellite views show no change in the amount of green plant produced per unit of rainfall, but humans can change the mix of tree, shrub, and grass.

SOURCE: 1998 BLACKWELL SCIENCE LTD., *GLOBAL CHANGE BIOLOGY* 4, 359-374   C. O. CECIL / VISUALS

Keeping tabs on an expanse of land that spans a continent requires the lofty vantage point of a satellite. Both of the new studies—by remote-sensing specialist Stephen Prince and his colleagues at the University of Maryland, College Park, and by Nicholson and her remote-sensing colleagues—rely on images from a series of National Oceanic and Atmospheric Administration satellites carrying an Advanced Very High Resolution Radiometer (AVHRR).

Intended to map snow, ice, and clouds, the AVHRR is good at recording vegetation changes as well. A ratio of surface brightness in the red part of the spectrum, where chlorophyll absorbs light, versus brightness in the near infrared, where green leaves efficiently scatter light, provides a "greenness" index that can gauge surface properties—for example, the proportion of the surface covered by vegetation.

When Nicholson and her colleagues calculated the greenness index for the entire AVHRR record—1980 to 1995—they found the edge of the Sahara doing a frenetic tango paced by rainfall, rather than a steady march. In the western Sahel, the area covered by their study, the southern boundary of the Sahara advanced southward and then retreated at least three times, moving as much as 300 kilometers over several years. "There is no progressive 'march' of the desert over West Africa," they conclude.

The satellite record also does not reveal any long-term degradation of the vegetated land. The greenness index can be related to the amount of rainfall to produce a measure of rain-use efficiency—the amount of green plants produced per unit of water. If something other than drought (overgrazing or soil erosion, for example) lowered plant productivity, rain-use efficiency would drop. But it remains constant if productivity simply varies with rainfall. Neither Nicholson, looking at the western Sahel over 16 years, nor Prince and his colleagues, who considered the full breadth of the Sahel between 1982 and 1990, found any net change in rain-use efficiency.

"I would say the remote-sensing observations confirm what most ecologists believed in the mid-1980s," says ecologist Dean Graetz of Australia's Earth Observation Center, part of the Commonwealth Scientific and Industrial Research Organization in Canberra. "The deserts aren't advancing; the Sahara was never marching south. Policy-makers are still impressed by the word 'desertification.' It is hypnotic, but it's not appropriate." Land degradation is a better term, he says, reflecting the more localized effects of such activities as grazing and foraging for fuel. Ecologists working in the Sahel have shown that around villages and wells, for example, overgrazing by cattle can shift vegetation from grasses to equally green, but less palatable, shrubs.

And that kind of degradation can be reversible, says ecologist William Schlesinger of Duke University. "If humans cause degradation, humans have the power to remediate the damage. That's encouraging." Graetz, however, fears that drought and misuse of the land will keep taking a toll on the health of the Sahel, even if they don't threaten its existence. **–RICHARD A. KERR**

ADDITIONAL READING

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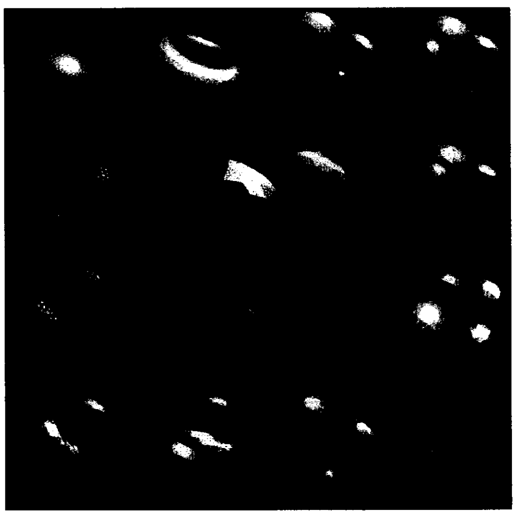
MATHEMATICS

Sphere Does Elegant Gymnastics in New Video

A tour de force of computer graphics gives the simplest solution yet to the venerable problem of turning a sphere inside out

More than 40 years ago, a University of Michigan graduate student named Stephen Smale laid down a challenge for future mathematicians. He proved an abstract theorem that had a startling corollary: An elastic sphere can be turned inside out, or "everted," without tearing or creasing it—providing the sphere can pass through itself, ghostlike. Smale did not give an explicit recipe for this sleight of hand, however. Since then, topologists have turned spheres inside out in media ranging from hand-drawn pictures to chicken-wire models to computer animations, but their solutions always seemed more complex than necessary.

Now, mathematicians George Francis and John Sullivan of the University of Illinois, Urbana-Champaign, have created a computer animation of a sphere eversion that is the simplest possible by several criteria. Demonstrated in a 6-1/2–minute video tour that will premiere next month at the International Congress of Mathematicians in Berlin and was shown in an abbreviated form at this month's Siggraph 98 convention in Orlando, Florida, their solution provides the most satisfying answer yet to Smale's challenge. It also shows how topologists are turning to computer graphics to solve some of their hardest problems. "In a real sense, the eversion question has become a benchmark for the use of computer technology in attacking problems of surfaces in three-dimensional space," says Thomas Banchoff of Brown University.



Sleight of computer. Animation turns a sphere inside out, using the least possible bending of the halfway point (center and bottom right).

FRANCIS AND SULLIVAN

A French mathematician, Bernard Morin, is generally credited with finding the first explicit eversion of the sphere in the early 1960s, and a computer-animated video called "Outside In," based on an idea by topologist William Thurston of the University of California, Davis, offers what may be the best-known example. Thurston's approach, however, is far from optimal. First, it allows the occurrence of many topological "events"—moments when two surfaces pass through one another, or when the curves of self-intersection abruptly change configuration. Second, it introduces an ornate pattern of corrugations to enable the sphere to twist around any potential kinks.

In the new eversion, Francis and Sullivan minimized bending by assigning their elastic surface an "energy" that increases when it is bent more tightly. At all stages of their eversion, the surface automatically keeps the lowest possible energy. And thanks to work done more than 10 years ago by Robert Kusner, a mathematician at the University of Massachusetts, Amherst, they already had an optimal configuration for the halfway point in the eversion, where the bending energy reaches a maximum.

Topologists had shown that at some stage in any sphere eversion, four sheets of surface