CLIMATE CHANGE

Landscape Changes Make Regional Climate Run Hot and Cold

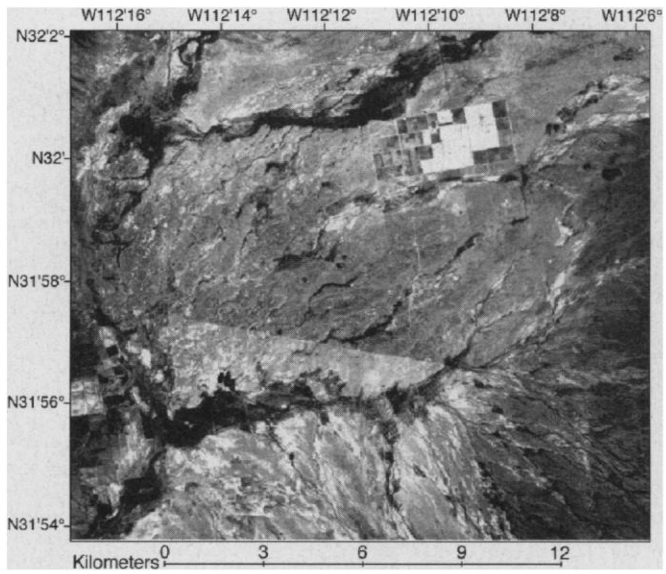
Researchers are only now measuring and trying to understand the impacts of agriculture, deforestation, and development on regional climate

Step across the U.S.–Mexican border anywhere in Arizona, and you will see why some climate researchers say that so far, global warming has been overrated compared to other human impacts on climate. Because of overgrazing on the Mexican side, there's little vegetation to release water vapor—a process called transpiration, which cools the air. Temperatures are as much as 4 degrees Celsius warmer on some afternoons than in the United States, just a few dozen meters away. The Mexican warming, which researchers at Arizona State University in Tempe are tracking, is only one of many regional climate changes that are starting to capture researchers' attention.

Climate change is best known on the largest and smallest scales: the global warming expected from the buildup of greenhouse gases, and the heat-island effect created by city buildings and pavement. But caught between the two are the climatic effects of deforestation, grazing, agriculture, and development, which have profoundly altered vast swaths of land on almost every continent. Climate researchers have long suspected that land use can change climate, but "there's very much a lack of studies that have been done at a regional level," says Randall Cerveny of Arizona State. Now, he and others are homing in on this middle ground, measuring and trying to understand the cooling effect of irrigated farming in Colorado, the warming and drying seen in deforested areas of the Amazon and elsewhere, and variations in storm intensity in the U.S. Northeast that match the weekly rise and fall of air pollution.

Computer climate models aren't refined enough for researchers to trace all of the causal links between human activity and regional climate. But recent results point to sizable effects. "We are having a bigger impact on the environment through our local and regional land practices than through the standard global greenhouse response," says Gordon Bonan, an ecologist who works with land-surface models at the National Center for Atmospheric Research (NCAR) in Boulder, Colorado.

One of the few regions that has been carefully studied is the plains of Colorado, where millions of acres of irrigated land have replaced dry prairie on the state's eastern front. A team of atmospheric scientists, ecologists, and hydrologists at Colorado State University in Fort Collins has found that over the last decade, in step with an expansion of irrigated lawns and an increase in water-hungry crops like corn, the mean July temperature on the eastern slope of the Rockies has dropped by as much as 2 degrees Celsius.



Continental divide. A satellite image reveals overgrazing to the south of the Arizona-Mexico border, which raises temperatures there.

SOURCE: B.S. PENN/UNIVERSITY OF TEXAS & C. K. MORITZ/ARIZONA STATE UNIVERSITY

To test whether irrigation really was the instigator, the Colorado State team used a computer model to compare heat and moisture fluxes in the existing land-cover pattern with the fluxes expected in two other scenarios: the pre-European landscape, when the prairie was unbroken, and a future landscape with even more irrigated farming. With more irrigation, they found, summer temperatures cooled measurably, allowing conifers favoring wet, cool conditions to establish themselves lower on the mountains. Driving the cooling, says Roger Pielke Sr., a professor of atmospheric sciences at Colorado State and a member of the study team, is transpiration from plants, which cools the air and produces clouds over the plains. Winds then sweep the cool, damp air upslope, cooling the nearby mountains and increasing precipitation there.

The reverse is true in another intensely studied area, the Amazon rainforest, where logging and burning have replaced large tracts of forest with grassland. Because grasslands cannot transpire as much water as lush vegetation or crops do, the tropical forest has become spotted with hot, dry patches. "You basically can create desertlike conditions in the middle of high-rainfall regions," says Michael Glantz, a senior scientist at NCAR. He and others estimate that temperatures are about 1 degree Celsius higher and precipitation up to 30% lower in large deforested patches, which Glantz says resemble a "lunar landscape." Similar effects have been seen in deforested regions of sub-Saharan Africa.

But determining just how much of the observed warming and drying is due to local human activity is often beyond current climate models. "Our ability to quantify the human land use effect on climate is still rather primitive," says Robert Dickinson of the University of Arizona, Tucson.

The problem, says Michael Oppenheimer, chief scientist at the Environmental Defense Fund in New York, is that the processes determining regional climate can take place at too fine a scale to be captured by most climate models, which often subdivide the landscape into regions 30 or more kilometers across and use a single number for the surface features and weather within each one. "What happens in a convective storm, cloud formation, and precipitation [are] treated at a relatively coarse scale in most models," says Oppenheimer. Pielke's modeling system at Colorado State is considered one of the best, able to simulate how soil and vegetation interact with the atmosphere in areas as small as 6 kilometers across.

The coarse picture of climate processes offered by most models makes it difficult to tease apart regionally induced climate effects from global ones. A global increase in carbon dioxide, for example, can dry and heat the atmosphere just as local deforestation does. Regional and global effects can also counteract each other, says Bonan. In the United States, he points out, increases in irrigated land "have mitigated some of the warming" produced by the greenhouse effect.

Some regional effects, however, are easier to disentangle from global ones. That was the case for the 7-day cycle of precipitation and storm intensity that Cerveny and his colleague Robert Balling have seen in data from the Eastern Seaboard of the United States. In 16 years of records, they found that 20% more rain fell over the Atlantic on Saturdays and Sundays than on weekdays; over a 50-year period they also logged weaker coastal cyclones on weekends—patterns that could hardly result from any gradual global change. Instead, Cerveny and Balling argued in *Nature* last summer, they reflect a buildup of industrial pollutants throughout the week. The haze, especially heavy at the end of the week, provides condensation nuclei for moisture, fostering the growth of heavy clouds, which shed rain on weekends. Although the weaker cyclones are more of a mystery, the authors believe that they're also tied to the rainfall increase.

Another unmistakably regional effect is seen halfway around the world, where decades of overirrigation have drained the Aral Sea, which straddles the former Soviet republics of Kazakhstan and Uzbekistan. Without the water's moderating effects, summers are hotter and drier, while winter temperatures have dropped.

The handful of scientists working full-throttle on regional climate change think these kinds of findings could ultimately make climate change seem a more immediate issue, and perhaps a more tractable one. "We framed the climate change problem … as a global problem with a global solution," says Roger Pielke Jr., a political scientist at NCAR. It's possible, he and others say, that focusing on how climate is changing by region will goad more individuals into taking action against, for example, deforestation, which could also have a ripple effect on global climate problems. "The global climate is the sum of these regions," says Bonan. "[Regional] change is occurring at a spatial scale that we can respond to. … It's occurring at a time scale that we can respond to." **–JENNIFER COUZIN**

Jennifer Couzin is a former intern at *Science*.

MEETING AMERICAN ASTRONOMICAL SOCIETY

Seeking Lasting Truths Among the Stars

AUSTIN, TEXAS—Thales, the ancient Greek astronomer, is said to have fallen down a well while gazing at the stars and not paying attention to his surroundings. Attendees at the American Astronomical Society meeting, held here from 4 to 9 January, could hardly be accused of the same fault, as they issued dozens of press releases and gave a string of press conferences. Although some results were oversold, some could be for the ages.

Soggy Cradles of Stars

The birthplaces of stars and planets are surprisingly damp, observations by the recently launched Submillimeter Wave Astronomy Satellite (SWAS) suggest. "We're seeing water everywhere we look," says SWAS principal investigator Gary Melnick of the Harvard-Smithsonian Center for Astrophysics in Cambridge, Massachusetts.

SWAS, launched by NASA on 5 December, is the first satellite ever to observe the universe at submillimeter wavelengths. This long-wavelength radiation, between the infrared and radio, is emitted by low-temperature molecules, including water, in the cool clouds of gas and dust that collapse to form new stars and planets. At the meeting, the SWAS team reported that their first 2 weeks of observations had revealed about one water molecule for every million hydrogen molecules in these cool clouds—about 10 times as much as expected from older observations made from an airplane.

"Their value for cool water is surprisingly high," says Ewine van Dishoeck of Leiden University in the Netherlands, "although I'm not yet convinced that they've looked at really cold clouds." If it holds up, the discovery of abundant water in the star-forming clouds could answer long-standing questions about the starting ingredients of planetary systems and about how the clouds lose enough energy to collapse into stars and planets.

Infrared satellites like the European Space Agency's Infrared Space Observatory (ISO) had already revealed large amounts of water vapor in the warmest parts (around 100 K) of the star-forming clouds. But submillimeter emissions from water in the cooler parts of the cloud are invisible to ISO. As a result, the chemistry of the cool parts of the clouds—direct precursors to new stars—has been a mystery. No one was sure whether the oxygen and hydrogen there combined to form water, and if they did, how much oxygen would be left to form molecular oxygen or carbon monoxide. Now, says Melnick's colleague David Neufeld of The Johns Hopkins University in Baltimore, the SWAS observations reveal that "almost all the oxygen [in the cool clouds] is in the form of water."

Heart of a cloud. Molecular hydrogen (red) and dust (blue) in the Orion Molecular Cloud.

CREDIT: ED ERICKSON, ANGIE SCHULTZ, SEAN COLGAN, AND NASA

The finding supports a 30-year-old theory that water molecules are the fundamental cooling agents in molecular clouds, which have to radiate excessive heat while collapsing into stars and planets. Water molecules have lots of energy levels and get easily excited by collisions with hydrogen molecules. When they fall back to their ground state, the energy is radiated away. "This is the first time that we can back up this theory with observations," says Melnick. **–GOVERT SCHILLING**

Govert Schilling is an astronomy writer in Utrecht, the Netherlands.

Superflares From Giant Planets

A giant planet around another star may have announced its presence 100 years ago, although 19th century astronomers did not realize what they were seeing, say two Yale University astronomers. Bradley Schaefer and Eric Rubenstein propose that an interplay between the magnetic fields of the star and a nearby giant planet could have caused a strange brightening of the star. The same mechanism, they believe, may explain similar flare-ups seen in other stars over the years.

In 1899, astronomers noticed a 10-fold brightening of S Fornacis, which lasted for a few hours. Since then, observers have seen a bunch of other apparently unremarkable stars pour out far more x-rays and visible light than usual for a few hours or days. The outbursts resemble solar flares, which go off when the sun's magnetic field suddenly rearranges itself. But these "superflares" are 100 to 10 million times more energetic, and no one has been able to explain them.

Surprisingly, Schaefer found that nine of the superflaring stars are very much like the sun. Any theory must explain why the sun doesn't have them, says Schaefer, and Rubenstein's model does just that.

In their duration and energy, the superflares are very much like the outbursts of a certain type of binary star, known as RS CVn binaries, says Rubenstein. In these systems, two magnetized stars orbit each other so closely