# Made in

Steamboat Springs was born as a ranching center in northwestern Colorado, but with a swoop of a cowboy hat, the town began transforming itself into a skiing-based resort community. This pairing of old and new is celebrated every February during the community's Winter Carnival with an event called skijoring, during which galloping horses tow obstacle-dodging skiers down the town's main street. The event requires skill, but then Steamboat has many good skiers—more winter Olympians than any other town in America. With justification, it calls itself "Ski Town USA."

This is middle America, mountain style, and just like cities in the rest of the country, Steamboat has a big Wal-Mart with a large American flag waving in the breeze. Inside, "Made in China" is stamped on televisions, salmon fillets and women's blouses. According to a 2005 article in *Business Week*, 70 percent of the goods sold by Wal-Mart are made in China.

Chinese exports of a different nature are evident 4,000 feet above the town, atop the ski area. There in the Storm Peak Laboratory, located on the Routt National Forest, atmospheric scientists are studying whether westerly winds deliver not only snow but contaminants from China's rapidly replicating coal-fired power plants, smelters and other industrial sources.

This work at Storm Peak is part of a relatively new and broad effort by U.S. scientists to understand how the fast-developing economies of China and other Asian countries are affecting the West, including its forests. The threat from mercury, ozone and microscopic particulates carried by winds to North America is small, but becomes significant when added to pollution from local and regional sources such as cities, power plants and agriculture operations.

In the United States, air quality has dramatically improved in recent decades, but Richard "Tony" VanCuren, an associate researcher at the University of California, Davis, says Asian pollution at increased concentrations will change that. Because of the additional pollution, he says, reaching a specified air quality goal at a particular locale in this country "may require additional reductions in North America emissions to compensate."

## FAR-REACHING EFFECTS

The evidence in the dust from China shows that pollutants have no boundaries—neither oceanic nor continental—and they certainly are not stopped by wilderness protection. Scientists now recognize that we're ultimately all downwind from somebody else. It just so happens that most national forests are now downwind of the world's fastest developing economy.

China is not the sole source for all this transoceanic pollution, but the robust expansion of its economy in recent decades implicates it as the primary source. Included in the migratory stew are tiny particulates called aerosols that originate in the wood-burning kitchen fires of rural Chinese villages, from cars and trucks now pouring onto urban streets and highways, and from the smokestacks of the smelters, chemical plants and coal-fired power plants that have sprung up across that massive country. Electrical demand in recent years has been

POLLUTANTS HAVE NO BOUNDARIES—NEITHER OCEANIC OR CONTINENTAL. IT JUST SO HAPPENS THAT MOST NATIONAL FORESTS ARE NOW DOWNWIND OF THE WORLD'S FASTEST DEVELOPING ECONOMY.

# China

by Allen Best

growing 13 percent a year, putting a new power plant online every seven or eight days. Even if this breathless march toward industrialization is now slowing as China shudders in response to the world's financial meltdown, it certainly has not stopped.

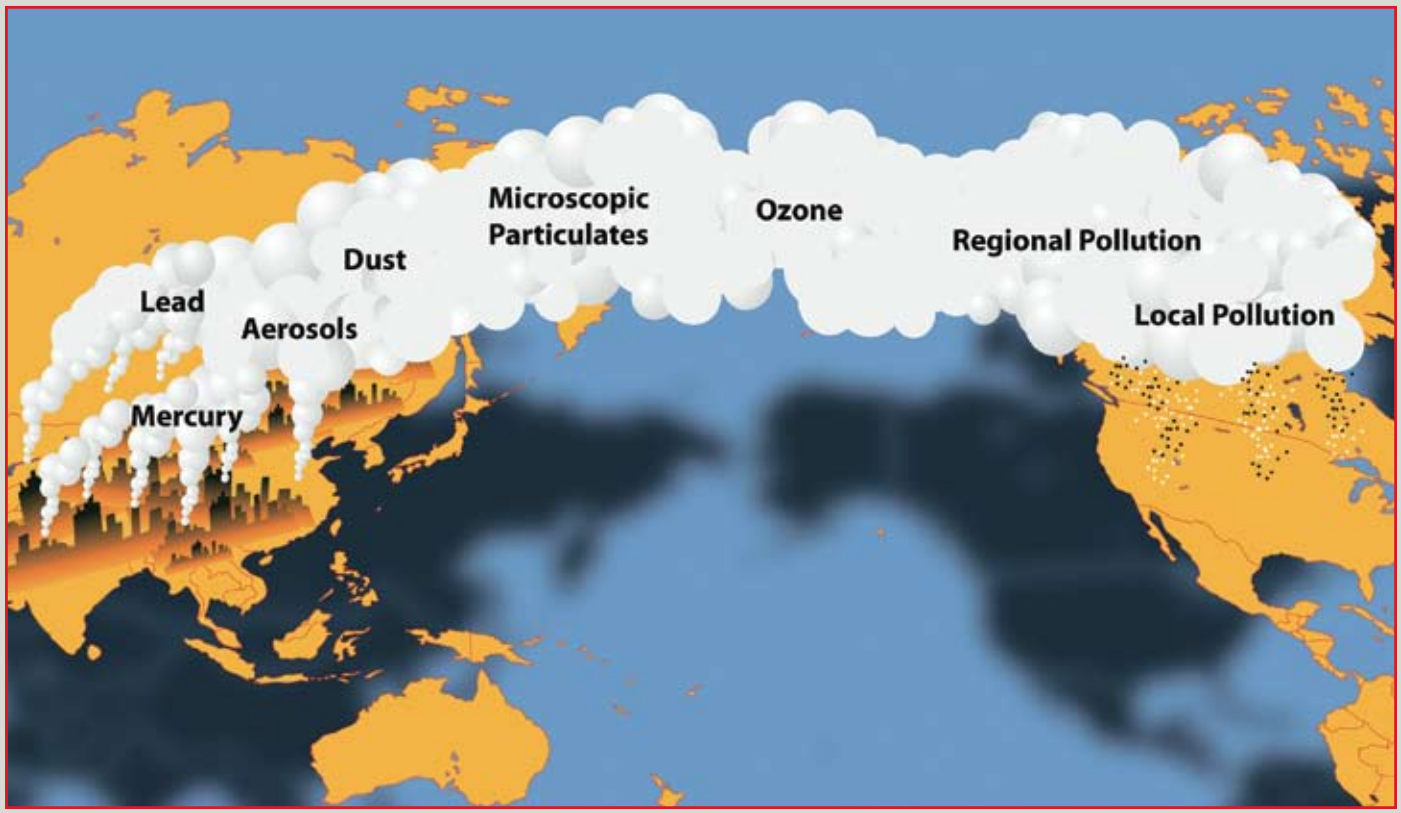
The most immediate victims of China's industrialization are the Chinese people themselves. A 2007 World Bank report estimated 700,000 people in China each year die prematurely because of the polluted air.

But just as a butterfly flapping its wings in the jungle can affect atmospheric conditions elsewhere, one country's developing economy can have far-reaching—and increasingly alarming—implications.

VanCuren says measurements taken at Hawaii's Mauna Loa Observatory in the 1960s and 1970s—just as the United States was getting serious about cleaning up pollution—first showed the presence of dust from the deserts of Asia. In time, scientists realized the dust was reaching North America, and by then so were other pollutants.

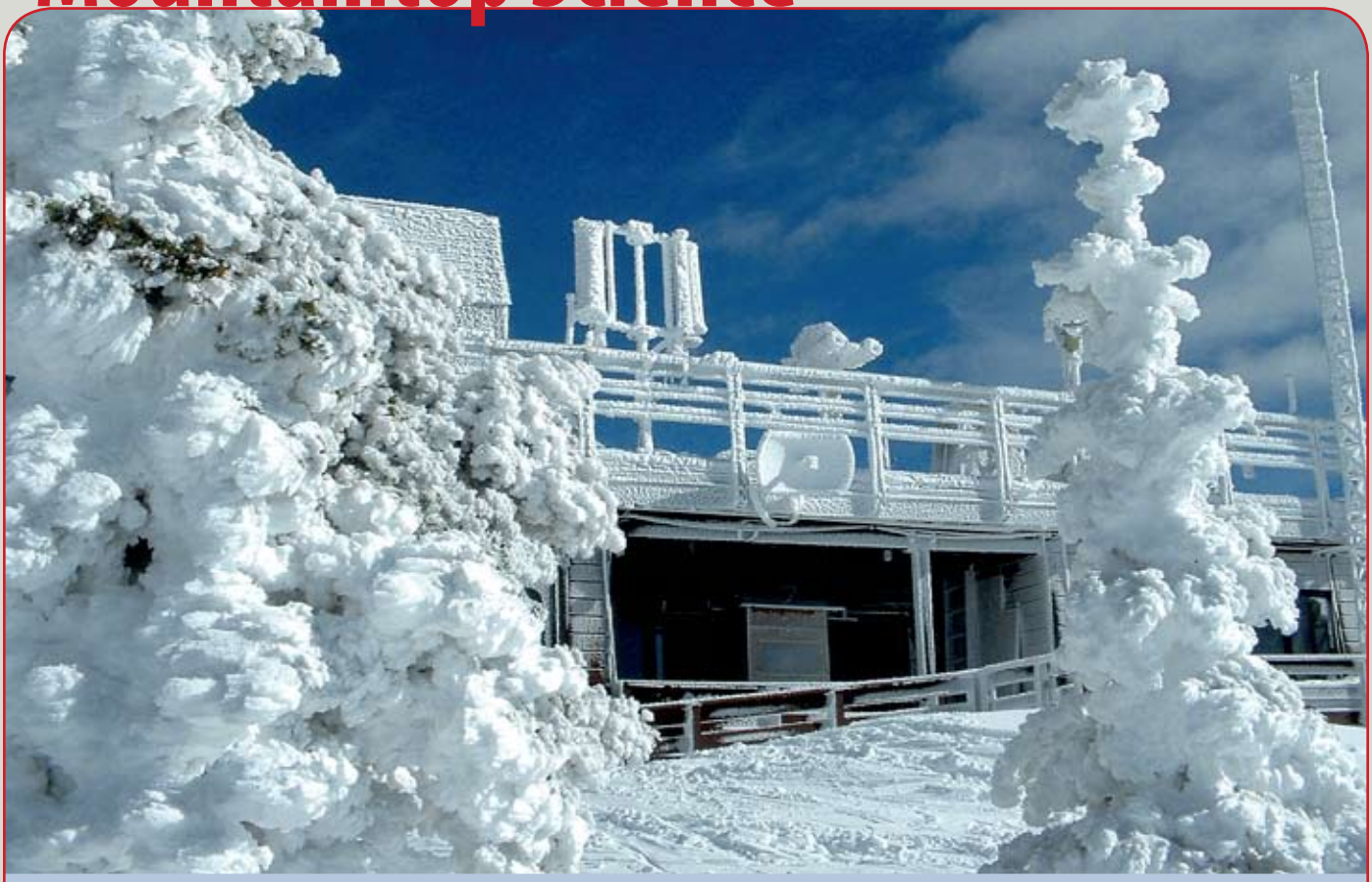
Many of the particulates that are carried across the Pacific from China are dispersed or washed out by rain, so that by the time they reach the West Coast, their threat is significantly decreased. The danger is in the addition. Think of Chinese pollution as a chaser of 80-proof whiskey after a pint or two of beer. The beer by itself may not challenge your sobriety. But the shot of bourbon on top of it could cause real trouble. That's the threat of the Chinese pollutants to the West and its forests.

The flow of aerosols and dust from Asia is small but nearly continuous. However, major windstorms during spring can kick up large plumes. One storm in 1998 blasted the West Coast from Los Angeles to Vancouver, B.C. From satellite images, scientists can trace the trajectory of the dust plumes




Mark Lesh, A-Frame Maps and Illustration

# Mountaintop Science



Randy Borys

Mercury, if naturally occurring at low levels, is toxic within aquatic and terrestrial ecosystems. "Mercury is harmful—period," says Anna Gannet Hallar, an atmospheric chemist who is director of the Storm Peak Laboratory atop the Steamboat ski area. "Understanding where it is coming from is important for both domestic regulations and international regulations."

Hallar is studying how mercury is being absorbed into the local ecosystems through clouds. With an elevation of 10,500 feet, the laboratory is well positioned for taking measurements.

The laboratory, founded in 1981, first consisted only of a trailer hauled to the site on one of the ski area's roads. In winter, ski lifts or snowmobiles provided access. The laboratory now includes a wooden building—by no means fancy, but large enough to accommodate Hallar as well as her spouse and professional associate, Ian McCubbin. Sometimes they spend several days at a time in the lab tending to the array of instruments for measuring the clouds and air. During winter, when the average annual snowfall measures twenty-five feet, that air is often filled with snow. When the skies are clear, though, the skylines provide a feast for the eyes, with mountains in every direction, including the Flat Tops Wilderness Area about thirty miles southwest and Rocky Mountain National Park about fifty miles to the east.

For all of its seeming isolation and purity, though, the clouds around the laboratory are greatly affected by smokestacks, tailpipes and farms both near and far away. One study completed several years ago found that clouds with high levels of pollution produced only half as much snow as was produced by clouds comparatively free of pollution. Moreover, the snow that did fall from the polluted clouds contained 25 percent less water. Sources of the pollution were not documented. But the implications are clear enough. After all, the snow falling on Steamboat ends up in Tucson, Las Vegas and San Diego.

Hallar arrived at the lab three years ago. She had grown up on a farm in Missouri, then trained to become a weather forecaster, perhaps on television, but discovered she much preferred being in the field and tinkering with data-collecting instruments. She got a doctorate in atmospheric sciences and now describes herself as a cloud chemist. She's in the right place for that. With her laboratory shrouded in clouds 30 percent of the time, she says, "there is plenty of cool science to be done."

and pinpoint their origins in the deserts of interior Asia. Crossing China, the storms pick up soot and other pollutants commonly called black carbon. A month-long study by V. "Ram" Ramanathan, director of the Center for Clouds, Chemistry and Climate at the Scripps Institution of Oceanography, during the spring of 2004 found that more than 75 percent of the black carbon over the West Coast of North America during spring months comes from across the Pacific.

It's not easy to monitor the content and path of pollution. In 2007, scientists used a small business jet, outfitted as a flying weather lab, which allowed them to determine the composition of these plumes as high as 51,000 feet over the Pacific Ocean. Flying from Denver to Alaska to Japan, the scientists were able to study the layers of dust and pollutants, which they believe may contribute to global warming.

High-mountain sites are particularly useful in detecting the pollutants. These sites are closer to the pollution-delivering wind currents, which are typically at 6,000 to 20,000 feet above sea level. In California, VanCuren has monitored sites at Donner Pass in the Sierra Nevada and Mt. Lassen in the Cascades as well as Oregon's Crater Lake National Park to better understand how plumes from Asia increase levels of pollution in North America.

Studies of lead isotopes found in California by soils scientist Stephanie Ewing of the U.S. Geological Survey further establish Asian origins. In air samples taken at several sites in California, she found small particles of lead. These lead particles have isotopes that clearly identify them as coming from Asia. The amounts are normally quite small, although larger concentrations can be detected during the spring dust storms. This isotopic fingerprinting of dust, she says, can be used to infer high proportions of other Asian materials.

Dan Jaffe, a professor of atmospheric and environmental chemistry at the University of Washington Bothell, first detected Asian pollutants arriving on the West Coast in 1997. To help peel back the identities of the invaders, he established an observatory at Cheeka Peak, located about 120 miles west of Seattle on Washington's Olympic Peninsula. Then, in 2004, he established an observatory on Mt. Bachelor, a ski area in central Oregon with an elevation of 9,000 feet.

THE DANGER IS IN THE ADDITION. THINK OF CHINESE POLLUTION AS A CHASER OF 80-PROOF WHISKEY AFTER A PINT OR TWO OF BEER. . . . THE SHOT OF BOURBON ON TOP OF IT COULD CAUSE REAL TROUBLE.

Because there are no major cities nearby, "most of the time, the air atop Mt. Bachelor is the cleanest air in the United States," he says. But especially during the spring storms, monitors spike with evidence of Asian pollution.

## BETTER AIR, MOSTLY

Air in the United States, say scientists, has improved. "The L.A. Basin especially has done just an enormous amount in terms of trying to clean up all kinds of emission and pollutants, and that really shows up in the data," says Scott Copeland, the U.S. Forest Service representative on an interagency air-monitoring program that has 172 stations around the country.

Denver, Salt Lake City and other cities still have brown clouds and notorious winter inversions that increase respiratory-related admissions at hospitals, but the air is nonetheless much better than it was thirty-five years ago.

U.S. Forest Service

*Pristine (top), hazy and smoky conditions in Oregon's Diamond Peak Wilderness.*

# The Ozone Effect

Ozone, when found in the atmospheric layer twenty to thirty miles above the earth's surface, is crucial for blocking harmful ultraviolet rays from the sun. For decades scientists have warned that a hole in this layer poses a significant threat to life on earth. But ground-level ozone—harmful to humans and to vegetation—is another matter, and it is showing up in increasingly higher concentrations across the rural West.

Ground-level ozone poses particular hazards to the young, the elderly and people with respiratory diseases. It also threatens forest health. Ozone causes some evergreens to lose their needles and suffer impaired ability to photosynthesize sunshine, carbon dioxide and water. Prolonged exposure can kill trees. Such damage has been documented for decades in California's ponderosa and Jeffrey pine forests, particularly in areas downwind from the Los Angeles Basin.

Urban areas have commonly been the vat for the ingredients that cause ozone. Ozone is created when exhaust from cars and trucks, industrial emissions and chemical solvents combine in the presence of sunlight. But high ozone concentrations in valleys hundreds of miles from any city have been linked to expanded oil and gas drilling in the Rocky Mountains. In early 2008, the Wyoming Department of Environmental Quality issued its first ozone advisory for the valley just west of the Wind River Range, where the nation's two largest natural gas fields are located. Ozone levels there have reached as high as 122 parts per billion volume, well over the eight hour average of 75 ppbv that was adopted by the U.S. Environmental Protection Agency in May as the safe health threshold.

Ozone is also an issue in the San Juan Basin along the Colorado–New Mexico border, where one monitor has recorded ozone at concentrations of 95 ppbv. The basin has 50,000 gas wells so far, plus two existing coal-fired power plants and the potential for a third. The forested areas near Colorado's Roan Plateau and Piceance Basin, another area of intense drilling activity, are also being monitored.

Researchers believe pollution from China is aggravating the ozone problem in the West. In a 2007 paper, Dan Jaffe of the University of Washington Bothell and co-author John Ray of the National Park Service reported a "significant increase" in ozone levels at seven of nine rural and remote monitoring sites they had studied—in all seasons of the year. In a 2008 appearance before the U.S.–China Economic and Security Review Commission, Jaffe said computer simulations suggest Asia pollution is responsible for just 3 to 10 percent of ozone in the West on most days. On a few days each year, however, the Asian contribution is as much as 37 percent of the federal standard. "While this contribution is relatively modest, it will certainly increase in the future and, when added to local pollution, it can push some areas over the air quality standard," Jaffe says.

Forests in New England are also doing better, the result of amendments to the federal Clean Air Act in 1990 that triggered changes at coal-fired power plants. Plants now burn more low-sulfur coal and have installed improved pollution control equipment.

Whether the pollution was from smokestacks or tailpipes, the nation has cleaned up its act. "By and large, we have done a good job of regulating industrial sources under the Clean Air Act," says Jaffe.

But air quality at times, and in places, has worsened. A new study by Christine Wiedinmyer and Hans Friedli of the National Center for Atmospheric Research shows that the increasing wildfires can be a significant source of mercury. Another study examined how wildfires contribute to ground-level ozone. Westerners have, until the last year, steadily increased the amount of driving they do as more houses are built in remote areas far from urban centers.

"All these things are leading to what I call a suburbanization of pollution," says Jaffe. The combination has created air problems in places like Idaho's Magic Valley, where Boise is located, that are more commonly associated with much larger cities.

Most vexing to regulators is ground-level ozone, which at high levels and prolonged exposure can damage both human health and high-elevation forests. Again, say scientists,

it's a case of Asian pollution exacerbating local and regional problems (see sidebar, p. 36).

The same is true for another type of pollution, the microscopic particles classified as $PM_{10}$ or smaller or $PM_{2.5}$ and smaller, which can damage lungs. Jaffe estimates that Asia contributes only small amounts on most days, but a few days per year as much as half of what is permitted by health standards is coming from overseas.

"Dust and pollution which is coming from 8,000 kilometers away will nearly always contribute less to your local air pollution than local sources," Jaffe points out. But in the future, the steady increase in China's manufacturing abilities will push air in the United States to unhealthy limits with far more frequency.

*Researchers at Storm Peak Laboratory on the Routt National Forest have been monitoring air for twenty-eight years.*

Patrick Joyce

## FINGERPRINTING MERCURY

Mercury is a problem with both local and global origins. In both cases, the source is coal.

"We know that most of the mercury that is falling out of the atmosphere is coming from coal combustion," says Jeff Sorkin, assistant regional air program manager in Colorado for the Forest Service. But tracing mercury deposition to specific sources, even local ones, is more difficult, he says.

The challenge is illustrated in Colorado's San Juan Mountains. For several years, children and pregnant women in the area have been warned to limit their consumption of fish caught in mountain lakes and reservoirs because of mercury contamination. Circumstantial evidence points toward power plants in nearby New Mexico as sources of this mercury. Analysis of snow that fell within Colorado's San Juan National Forest at a place called Molas Lake further suggests—but does not yet confirm—origins from two coal-fired power plants in the Four Corners area.

But how much mercury from Asia is ending up in the San Juan, or other mountain ranges of the West, is still not clear. "That's the $64,000 question," says Jaffe. "That's the one everyone wants to know." Mercury, he says, is a very hard element to measure, and its chemical transformations are not well understood. But what is known is that coal in the United States contains much less mercury than Chinese coal. Jaffe says he believes 10 to 30 percent of total deposition of mercury in the United States comes from Asia. Computer modeling of long-range transportation estimates that Asia contributes 27 percent of mercury deposition in Colorado (see sidebar, p. 34).

So far, there's a close correlation between China's economic growth and pollution emissions. Steven Massie, a research scientist at the National Center for Atmospheric Research in Boulder, Colorado, reports that nitrogen dioxide emissions in China—detected by satellites passing overhead—are almost perfectly matched with China's 10 percent growth in gross domestic product in recent years. The most significant sources of nitrogen dioxide are internal combustion engines and thermal power stations.

FROM SATELLITE IMAGES, SCIENTISTS CAN TRACE THE TRAJECTORY OF THE DUST PLUMES AND PINPOINT THEIR ORIGINS IN THE DESERTS OF INTERIOR ASIA. CROSSING CHINA, THE STORMS PICK UP SOOT AND OTHER POLLUTANTS COMMONLY CALLED BLACK CARBON.

Jaffe, in testimony last August before the U.S.–China Economic and Security Review Commission, projected an increase in emissions from China of 50 to 200 percent by the year 2020. The increase, he said, was not inevitable. Advanced pollution control—technologies he believes the United States should assist China in adopting—are available.

"The thing that's really important," says Jaffe, "is that if we don't talk about these things, and discuss them, they will never get talked about by the policymakers, whether they be in California or in Asia."

If the cost to the United States and its high-elevation forests today is relatively minor, the trends during China's recent industrial expansion concern scientists. VanCuren notes that California, in particular, has spent a lot of money cleaning up its air during recent decades. But the pollution from China, he says, may soon present an added expense, as steps are taken to reduce ozone, dust and other pollution. With that, the true cost of those plasma TVs will be rung up. PM