METEOROLOGY

Rivers in the Sky Are Flooding The World With Tropical Waters

When mid-latitude storms tap into the great stores of moisture in the tropical atmosphere, the rain pours and pours, rivers rise, the land slides, and locusts can swarm

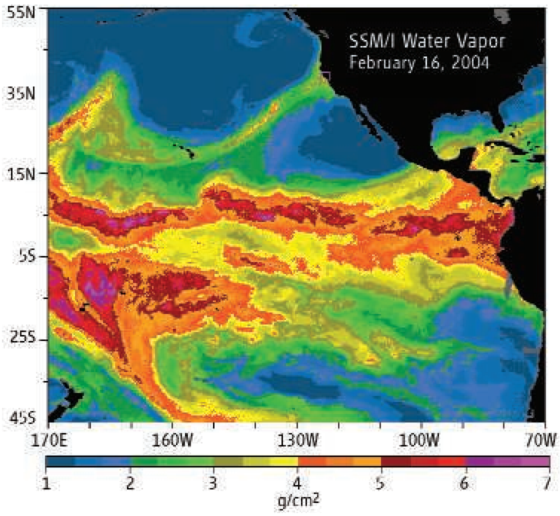
Call them tropical plumes, atmospheric rivers, Hawaiian fire hoses, or Pineapple Expresses. Whatever the label, meteorologists are now recognizing the extent to which these streams of steamy tropical air transport vast amounts of moisture across the globe, often leaving natural disasters in their wake. When a classic atmospheric river tapped tropical moisture to dump a meter of rain onto southern California in January 2005, it triggered the massive La Conchita mudslide that killed 10 people. Torrential rains fed by an atmospheric river inundated the U.S. East Coast last month, meteorologists say, and researchers recently showed that atmospheric rivers can flood places such as northwest Africa as well, with equally dramatic effects.

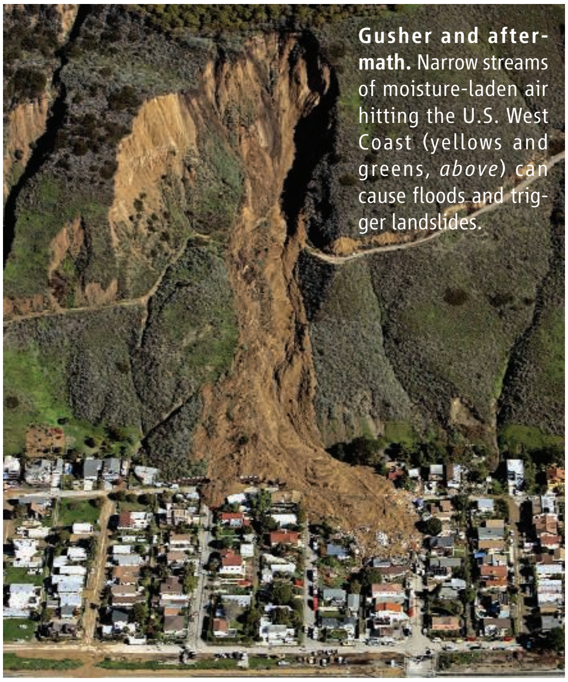
Researchers are now probing the workings of these rivers in the sky in hopes of forecasting them better, not only day to day but also decade to decade as the greenhouse builds. When atmospheric rivers make the connection to the moisture-laden tropics, "all hell can break loose," says meteorologist Jonathan Martin of the University of Wisconsin, Madison.

Weather forecasters have long recognized the importance of narrow streams of poleward-bound air. A glance at satellite images of the wintertime North Pacific Ocean shows great, comma-shaped storms marching eastward, their tails arcing back southwestward toward Hawaii and beyond. These storms are redressing the imbalance between the warm tropics and cold poles by creating an atmospheric conveyor belt. Cold air sweeps broadly southward behind the cold front that runs along the tail, and warm air is driven poleward along and just ahead of the front. It is this warm and inevitably moist stream paralleling the front that has come to be known as an atmospheric river.

Those storms sweeping across the mid-latitudes are obviously major conduits in the atmosphere's circulation system, but few appreciated quite how major until 1998, when meteorologists Yong Zhu and the late Reginald Newell of the Massachusetts Institute of Technology in Cambridge analyzed globe-circling weather data on winds and their water content. Although the three to five atmospheric rivers in each hemisphere at any one time occupied just 10% of the mid-latitudes, they found, the rivers were carrying fully 90% of the moisture moving poleward.

In 2004, meteorologist Martin Ralph of the National Oceanic and Atmospheric Administration's (NOAA's) Environmental Technology Laboratory in Boulder, Colorado, and his colleagues showed just how narrow atmospheric rivers really are. By parachuting instrument packages along a line across the cold fronts of 17 storms, they found that the core of a river—a jet of 85-kilometer-per-hour wind centered a kilometer above the surface—is something like 100 kilometers across. But the river is so moist that it moves about 50 million liters of water per second, equivalent to a 100-meter-wide pipe gushing water at 50 kilometers per hour.





Gusher and aftermath. Narrow streams of moisture-laden air hitting the U.S. West Coast (yellows and greens, *above*) can cause floods and trigger landslides.

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Such a "fire hose of water aimed at the West Coast," as Ralph describes it, can do serious damage. Ralph and colleagues combined NOAA field studies near the coast of northern California with satellite observations in a detailed study of the February 2004 flooding of the Russian River, they reported in the 1 July *Geophysical Research Letters*. In that case, an atmospheric river extended 7000 kilometers through Hawaii, linking up with moisture-laden air from the tropics.

At the California coast, the mountains directed the oncoming atmospheric river upward, wringing out enough rain to create record flows on the Russian River. Near-record flows hit rivers and streams along 500 kilometers of the coast and across the breadth of California. Ralph and his colleagues also found that similar atmospheric rivers caused all seven floods on the Russian River since October 1997.

Other researchers are looking at atmospheric rivers around the world. In an upcoming paper in *Weather and Forecasting*, meteorologists Peter Knippertz of the University of Mainz, Germany, and Jonathan Martin of the University of Wisconsin, Madison, will report on an atmospheric river that dumped 8 centimeters of hail on central Los Angeles in November 2003 and went on to deliver heavy precipitation to Arizona. Last year, they described three cases on the west coast of North Africa of extremely heavy rains in 2002 and 2003 fed by atmospheric rivers. Some areas received up to a year's worth of precipitation in one storm. An autumn 2003 drenching helped create favorable breeding conditions for desert locusts, leading to devastating outbreaks in large parts of northern West Africa.

The latest studies remind meteorologists that atmospheric rivers and their flooding are commonplace. By studying them, meteorologists are hoping to improve forecasts of heavy rains and flooding; in the case of the Russian River, they expected 13 centimeters of rain, but 25 centimeters fell, setting off the record flood. Advances will come from improving the observations of atmospheric rivers offshore and correcting errors in forecast models, particularly as they simulate the encounter between atmospheric rivers and mountains. Even climate modelers hoping to predict precipitation in a greenhouse world will have to get a better handle on the rivers in the sky.

–RICHARD A. KERR