Diffusion takes a controversial spin

A drop of red dye in the middle of a large body of undisturbed liquid spreads out evenly, expanding into a spherical cloud of color centered on the dye's starting point. What would happen if the same diffusion experiment were done in a body of liquid being rapidly rotated as a whole? Recent theoretical calculations predict that for particles the size of protein molecules whirled in a high-speed centrifuge, such rotation may significantly slow down diffusion of the molecules. Moreover, the expanding cloud's shape would be oval rather than spherical.

This prediction contradicts a long-standing assumption that thermodynamic processes such as diffusion and the flow of heat are largely unaffected by the motion of the medium in which the process takes place. Researchers usually assume that the rotation of the medium is so much slower than any particle motion that it would have a negligible effect on the particles. However, the question of whether an effect could ever be observed has remained controversial.

"This situation is exactly equivalent to our usual neglect of the Earth's rotation when we do experiments in laboratories," says chemical engineer Gregory Ryskin of Northwestern University in Evanston, Ill. "In most practical situations, when you have diffusion, say, of sugar dissolving in water, it's actually an extremely good approximation. However, diffusion can also occur with particles that are so large that the approximation may break down." Ryskin's calculations, reported in the Sept. 26 PHYSICAL REVIEW LETTERS, provide one of the clearest examples of a situation in which the assumption may not hold.

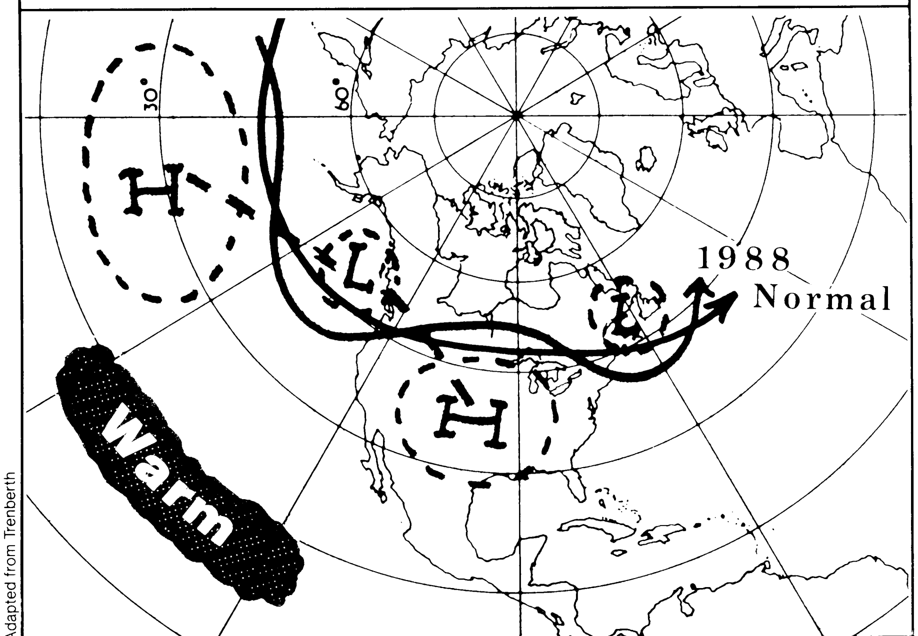
In Ryskin's model, a diffusing particle pushes aside liquid, causing the liquid to flow out of the way. The rotation of the liquid as a whole twists this particle-induced liquid flow into cylindrical columns above and below the diffusing particle. Those columns move with the particle and slow it down. "In this phenomenon, it's not the force on a particle itself that gives rise to the effect," Ryskin says. "It is the Coriolis force on the fluid motion caused by the particle."

Normally, particle diffusion occurs from a region of high concentration of particles toward one of low concentration. In a sense, the particles flow down the concentration gradient. Ryskin's calculations suggest that in a rotating frame of reference, some diffusion also occurs at right angles to the gradient, a surprising effect that no one has ever thought to look for.

Ryskin's theoretical predictions have yet to be tested experimentally. The effect would be most apparent in a system in which the diffusing particle's density matches that of the liquid, he says.

"If diffusion is influenced by the rigid-body rotation of the system, the theory of the centrifuge, used in biochemistry and polymer science for the characterization of macromolecules, needs modification," Ryskin says. A decrease in the mobility of large molecules diffusing through a rotating liquid may account, at least in part, for some puzzling anomalies observed in the use of high-speed centrifuges for analyzing DNA molecules. *– I. Peterson*

Hot-and-cold Pacific fed Midwest drought



Adapted from Trenberth

Warm Pacific water farther north than usual led to this summer's severe Midwest drought, a group of meteorologists suggests. Arrows show path of jet stream.

A group of meteorologists attributes this summer's severe drought in the north-central United States to a region of warm Pacific water that persisted unusually far north of the equator last spring. "The greenhouse effect almost certainly did not play a primary role in the drought," contends Kevin E. Trenberth of the National Center for Atmospheric Research (NCAR) in Boulder, Colo.

During April, May and June, water 1°F to 2°F warmer than normal occupied an area southeast of Hawaii, between 10°N and 20°N latitude and 120°W and 150°W longitude, Trenberth told an audience at the University of Maryland in College Park last week. Forecasters consider a warm Pacific region in spring normal, "but the northern location of the warm water was unusual," Trenberth told SCIENCE NEWS.

He says abnormally cold sea temperatures and dry air at the equator caused the warm water to settle so far north. "Water at the equator went through one of the coldest periods ever recorded," with temperatures 3°F to 4°F below normal, Trenberth reports. He says the cold equatorial water resulted from feedback between the atmosphere and the ocean, which "constantly force changes in each other."

Along with NCAR colleague Grant W. Branstator and Phillip A. Arkin of the National Oceanic and Atmospheric Administration's Climate Analysis Center in Camp Springs, Md., Trenberth analyzed ocean and atmospheric data and satellite photographs of the Pacific – a major source of U.S. weather – for the months before and during the period of extremely low rainfall in the Midwest. The satellite images show that the warm-water region, with its thick cloud cover and heavy rainfall, acted like a rock in a river, diverting westerly winds northward.

This obstacle effect, says Trenberth, pushed the moisture-bearing jet stream into Canada and allowed a strong region of high pressure to build over the central United States. Once established, the high-pressure ridge hindered moisture from reaching the parched area. Trenberth says the greenhouse effect "could have been a small enhancement, making the summer heat waves even hotter."

Although areas in the West and Southeast have experienced prolonged periods of low precipitation during the past several years, those droughts have resulted from different climatic idiosyncrasies, Trenberth says. *– C. Knox*