Earth's Turbulence Stirs Things Up Slower than Expected

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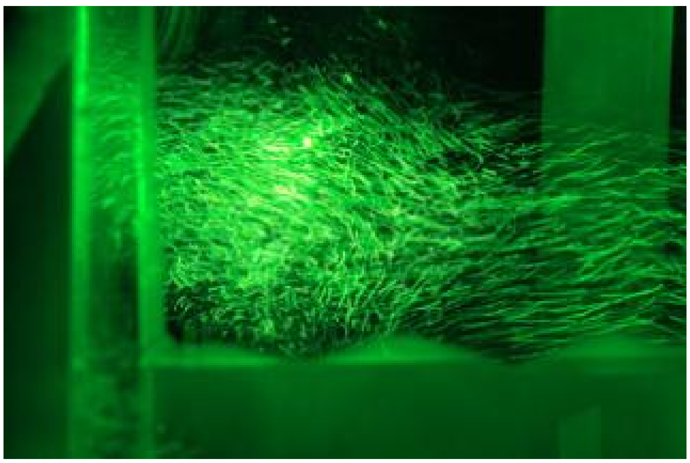

Particles (in false color) seen as they move in turbulent water, viewed in a time-lapse photograph.

In a simple world rivers would flow in straight lines, every airplane ride would be smooth, and we would know the daily weather 10 years into the future. But the world is not simple -- it is turbulent.

That's good news, since turbulence helps drive natural processes essential for life. Unfortunately it also means we are never 100 percent sure it won't rain on Saturday.

"Turbulence is the last major unsolved problem of classical physics," explains Eberhard Bodenschatz, professor of physics who studies turbulence with his research group at Cornell and the Max Planck Institute (MPI) for Dynamics and Self-Organization, Germany.

The group recently moved closer to a solution by measuring how two tiny polystyrene spheres in turbulent water separate based on how far apart they initially are from each other. The results were published in the Feb. 10 issue of Science.

The findings suggest that, for almost every turbulent flow on Earth, including violent volcanic eruptions, particles separate more slowly than expected. This discovery could help improve models of dispersion of pollutants and bioagents and even help explain how crustaceans find food, mates and predators by sensing odors in the ocean depths.

Turbulence occurs when a gas or fluid, like air or water, is pushed at high speeds or on large scales, and is characterized by chaotic, seemingly random, flow patterns. Because of its complexity, turbulence is very efficient at mixing: a solution of two liquids, such as cream and coffee, will mix much more quickly if the flow is turbulent than if it is not.

As a white-water rafter might toss a stick into rapids to observe its behavior before jumping in, physicists watch particles in turbulence to understand the flow. A key measurement is how quickly two particles will separate, or "pair dispersion."

In the 1920s, British scientist L.F. Richardson predicted that pair dispersion should grow quickly, as time multiplied by itself twice (time cubed), independent of the initial separation of the pair -- a statement known as the Richardson-Obukhov law. In the 1950s, Australian-born Cambridge mathematician G.K. Batchelor added the amendment that for short timescales, pair dispersion is not independent of initial separation and should grow more slowly, as time multiplied by itself (time squared).

Until recently, the difficulty of photographing tiny particles at high speeds made direct measurements of these predictions impossible.

"When we first planned these experiments, fast enough cameras didn't exist," said Cornell graduate student Nicholas Ouellette, a co-author of the Science article. The final experiment used three high-tech digital cameras able to record up to 27,000 pictures per second of several hundred polystyrene spheres simultaneously in 8 cubic inches of water. The diameter of the spheres was about one-fourth the thickness of a human hair -- a thickness needed because it matched the smallest eddies in the turbulent water.

The experiment showed that when the initial separation of the spheres is large relative to the turnover time of the eddies, they will obey Batchelor dispersion, independent of the turbulence's severity. However, if the initial separation is smaller, then the particles will only exhibit Batchelor dispersion initially before transitioning to behavior consistent with the Richardson-Obukhov law.

"Right now new technology -- like our fast cameras -- is making experiments possible that just 10 years ago were considered impossible. It's a very exciting time to be in the field," Ouellette said.

The other authors of the Science paper are Haitao Xu, Cornell and MPI for Dynamics and Self-Organization, lead author Micka?l Bourgoin, Laboratoire des Écoulenments Géophysiques et Industriels, France, and Jacob Berg, Ris? National Laboratory, Denmark.

Source: Cornell University, By Thomas Oberst