From surface scum to fractal swirls

Flecks of soapy scum floating on the surface of water draining out of a bathtub sometimes gather into intricate patterns. The geometry of the resulting patterns provides a snapshot of currents within the draining water. These convoluted flows cause local upwelling in some locations and downwelling – where floating particles tend to collect – in others.

Two physicists have now applied this phenomenon to demonstrate a direct link between the complicated motion of a fluid and the resulting fractal pattern displayed by an aggregate of floating particles. Fractals are complex shapes that look roughly the same whether greatly magnified or viewed from a distance.

Researchers have noted fractal patterns in the shapes of clouds, the branching of blood vessels, the jaggedness of coastlines, and the roughness of fractured rocks. But there has been no obvious connection between such patterns and the physical processes responsible for creating them.

"[Our] research may be a first step on the road to understanding why fractals exist in nature," says John C. Sommerer of the Johns Hopkins University Applied Physics Laboratory in Laurel, Md. Sommerer and Edward Ott of the University of Maryland in College Park report their findings in the Jan. 15 SCIENCE.

The researchers' apparatus – their scum machine – consists of a cylindrical tub sitting inside a larger, taller cylindrical tub. Both are filled with a thick syrup. A pump forces the syrup upward between the inner and outer cylinders. The flowing syrup crosses over the inner cylinder's lip, then moves downward to drain out of a central spout. Tiny plastic spheres that fluoresce in ultraviolet light float on the liquid's surface.

John C. Sommerer/SCIENCE

Fractal pattern formed on a flowing liquid's surface

With steady pumping and under perfectly symmetrical conditions, these tracer particles would simply converge on the exit. But a sequence of pumping pulses produces a complicated, unstable flow, and the particles gather wherever the flow is downward.

By photographing the tracer particles under ultraviolet light, the researchers obtain images from which they can derive the Lyapunov exponent, which indicates how rapidly the paths of nearby particles spread apart. They can also measure the fractal dimension – the intricacy – of the resulting pattern.

The results show that the fractal characteristics of the patterned surface quantitatively mirror the physical process that created the pattern, as characterized by its Lyapunov exponent.

"This establishes that a fractal's dimension is related in some way to the set of forces that produce it," Sommerer says. "In our experiment, we have a fractal, and we know where it comes from."

– I. Peterson

Once bashful El Niño now refuses to go

It took a long time to show its face, but the El Niño warming that finally arrived last year and upset world weather has turned into a lingering guest, remaining in place far longer than expected, meteorologists with the National Weather Service reported last week.

El Niños represent periodic blips in the global climate that develop when warm water from the western equatorial Pacific Ocean spreads eastward in concert with shifting patterns of atmospheric pressure called the Southern Oscillation. These so-called warm events alter typical weather patterns around much of the globe, bringing rains to some regions and droughts to others.

As early as 1989, some meteorologists reported seeing signs of a developing El Niño, but the real warming did not begin until late 1991, reaching full force in early 1992. The El Niño played a role in causing North America's mild winter last year and contributed to a severe drought plaguing southeast Africa, according to meteorologists at the weather service's Climate Analysis Center (CAC) in Camp Springs, Md.

By the middle of last year, a drop in sea-surface temperatures in the central Pacific and other weather changes appeared to herald the death of the El Niño. Both human forecasters and computer models called for normal or colder-than-normal conditions to develop in the equatorial Pacific by the end of 1992 (SN: 7/4/92, p.5). But weak El Niño conditions continued throughout the year and then unexpectedly gained strength in December, says CAC's Vernon E. Kousky.

"It is fair to say that what was predicted by our model, by and large, was not correct," says Tim P. Barnett, an oceanographer at the Scripps Institution of Oceanography in La Jolla, Calif. Barnett is one of several scientists attempting to forecast conditions in the Pacific using computer models.

Stephen Zebiak of the Lamont-Doherty Earth Observatory in Palisades, N.Y., is less critical of the model he uses, though it also called for slightly subnormal temperatures by this time. "The model basically describes the longer term trends rather than the month-to-month changes." The current warming reported by the CAC may just be a temporary step backward in the general march toward cooler conditions in the central equatorial Pacific, Zebiak says.

Though not forecasted, the continuing warmth should make many residents of the western United States happy. The pool of warm water has spawned atmospheric convection in the central Pacific, which injects moisture into the atmosphere. That convection contributed to the storms that dropped needed rain and snow on drought-plagued California, Nevada, and Oregon during the last two months, Kousky says.

Forecasters and modelers do not yet know what to make of the lingering warmth in the central Pacific. But Barnett thinks it could reflect a long-term climate change there. Looking at temperature records of the equatorial Pacific going back to 1900, Barnett last week found indications that the average regional temperature west of the international dateline climbed considerably between the 1950s and mid-1970s.

If such a shift did actually occur, then the apparent warmth of the last few months could represent an artifact of the way meteorologists analyze temperature data. When measured against a long-term mean that includes the period prior to the climate shift, the current conditions would register as warmer than normal, leading to the appearance of a lingering El Niño. But when measured against the new average, established after the mid-century warming, the current conditions would register close to normal, Barnett says.

– R. Monastersky